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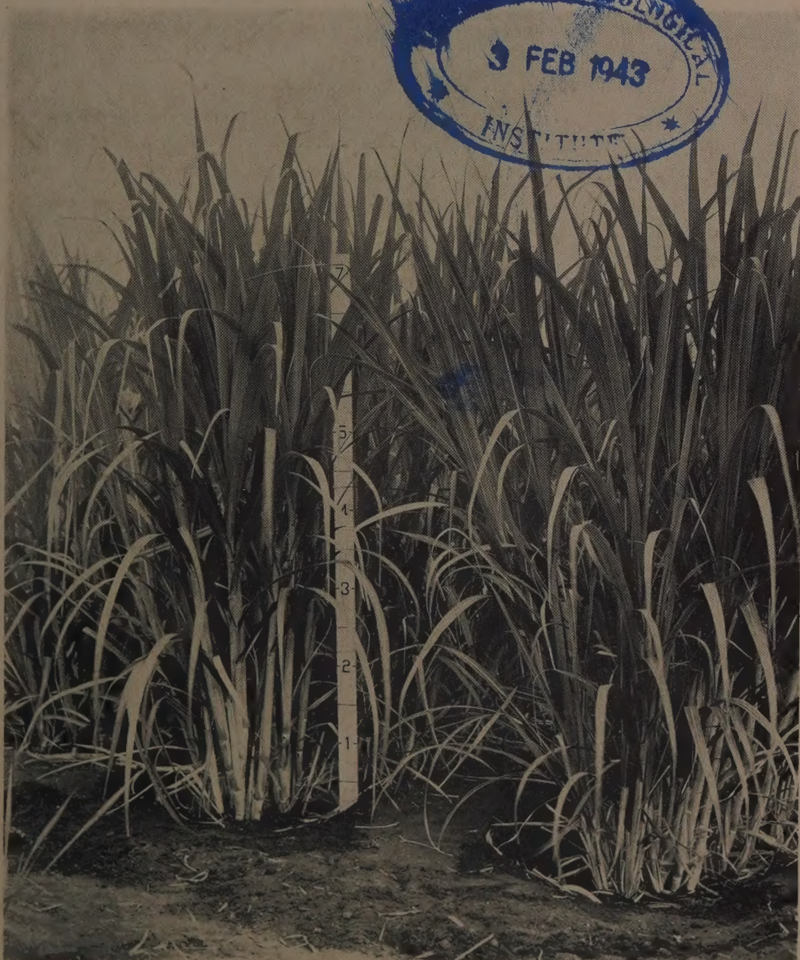
THE HAWAIIAN PLANTERS' RECORD



This excellent crop of 32–8560 cane has been developed from an application of only forty pounds of nitrogen per acre, applied at six weeks. Age four months.

THIRD QUARTER 1942

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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THE HAWAIIAN PLANTERS' RECORD

Vol. XLVI THIRD QUARTER 1942 No. 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

The First Application of Nitrogen

A comparison of fertilizer practices in use on the different plantations will show a considerable difference in the efficiency of applied nitrogen as measured by pounds of nitrogen supplied per ton of cane produced. Opinions have been expressed that some of the inefficiency may be associated with the use of an excessive initial application when the crop is only one or two months old, for at this stage of its growth the crop runs into its greatest competition (from weeds, soil organisms, and leaching) for the applied nitrogen fertilizer. But there has been a difference of opinion as to what amount of nitrogen constitutes an excessive application at this age. Perhaps the photographs we have taken of a crop of 32–8560 in Makiki Expt. 20 ATN, exactly four months after it was planted in May, may have a story to tell us.

The Makiki soil where this experiment is located is one which is quite low in both its total and available nitrogen status, hence it is unlikely that there has been any considerable amount of nitrogen supplied by the soil during these first four months of growth; this is quite evident when we look at the photograph of the cane which had received no nitrogen fertilizer (see page 104—left).

On the other hand, the photograph shown on the cover is one of this same crop which had received only 40 pounds of nitrogen per acre at the age of six weeks. The stalk development of this cane has been exceptionally rapid, and it is extremely doubtful that it could have been much better even if the initial nitrogen application had been a larger one.

Thus it would seem that if an excellent crop, like the one shown on page 104—right, can actually be developed in a period of four months, on a low-nitrogen soil during the best growing weather of the year, from an application of only 40 pounds of nitrogen per acre, then an initial amount which is much larger than this is probably excessive and may be inefficiently used by the crop concerned.

R. J. B.

32–8560 plant cane at four months. Left—grown without application of nitrogen fertilizer. Right—grown with only forty pounds nitrogen per acre applied at six weeks.

The Calcium Phosphate Precipitate in Limed Cane Juice

By Hugo P. Kortschak

The results of recent experimental and theoretical investigations of calcium phosphate are applied to the precipitates formed on liming cane juices. These precipitates cannot be described in terms of definite chemical compounds. The decreasing pH is caused by oxolation and by absorption of calcium. The high calcium content of clarified juice is due to several different factors.

I. *The Composition of the Precipitate:*

Although lime has been used for over a thousand years as a clarifying agent for cane juice, there is still much speculation on the nature of the precipitate formed. This precipitate has been described as hydroxyapatite (2, 11, 17), tri-calcium phosphate (2, 5, 7, 10, 18), di-calcium phosphate (10), or a solid solution of lime in secondary calcium phosphate (3).

This confusion is only natural, as the reaction of phosphoric acid with calcium phosphate has remained obscure until recently. In the past few years it has become apparent that the difficulty lies in attempts to describe the precipitate in terms of definite compounds. Any such attempt is doomed to failure, as precipitated calcium phosphate may have any composition between $CaHPO_4$ (or even slightly more acid) and $Ca(OH)_2$, depending on the conditions of precipitation (4, 6).

Practically all theoretical investigations of calcium phosphate represent an attempt to attain equilibrium. Although it is universally recognized that in cane juice clarification equilibrium is not reached, yet conclusions drawn from such experiments are applied. Fortunately, in one of the most extensive investigations of calcium phosphate solubility, that of Bassett (1), conditions were much like those which occur in the sugar mill. Bassett made up his samples using solutions of di-calcium phosphate, phosphoric acid, and milk of lime. He found it necessary to boil his solutions *at least four weeks* before equilibrium was approached. This makes it evident that the only use we can make of such measurements at equilibrium is to indicate the manner in which the precipitate will change with time.

It has been shown that freshly precipitated calcium phosphate does not possess a crystalline structure (7, 9), except for the presence of usually small amounts of $CaHPO_4$. (Even the crystals which appear to be $CaHPO_4$ may contain a much larger proportion of lime [1, 6].) Now, when a substance is amorphous, there can be only one criterion as to whether or not it is a definite chemical compound, and that is constancy of composition. Both in the case of analyses of filter cake, and in more closely controlled laboratory experiments, there is no indication of a constant ratio of lime to phosphate in the precipitates. Records at this station show that in filter cake the ratio of CaO to P_2O_5, in equivalents, can vary from 0.12 to 5.68. These extremes are, of course, due to the presence of insoluble phosphate, or undissolved lime, but the data of Bond (3), which cannot be affected in this way, show a range from 0.47 to 2.38. The ratios for the definite compounds are:

Mono-calcium phosphate, 0.33; di-calcium phosphate, 0.67; tri-calcium phosphate, 1.00; tetra-calcium phosphate, or hydroxyapatite, 1.33.

Although any composition may be described as due to solid solution of two definite compounds, the term does not seem very applicable to these precipitates, implying, as it does, the presence of at least two components which retain their identity, although intimately mixed. It is not possible to say of one calcium atom that it is part of the di-calcium phosphate, and that another belongs to the tertiary salt. If the precipitate is called a solid solution, the components are not the various definite calcium phosphates and lime, but the ions of calcium, phosphate, hydrogen, and hydroxyl, and water, not to mention a dozen other "absorbed" substances.

To summarize: the precipitated calcium phosphate obtained on liming cane juice is not a chemical compound. It has no definite composition, not even a definite structure. It is an amorphous mass, whose composition may vary between very wide limits, depending on the conditions under which it is precipitated.

II. *The Increasing Calcium Content of the Precipitate:*

The ratio of calcium to phosphate in the precipitate increases on standing, resulting in a decrease in the pH of the juice. This has long been known, both in cane juice and in water solutions, and is usually ascribed to the hydrolysis of the calcium phosphate, liberating either free phosphoric acid (5, 7), or mono-calcium phosphate (17).

This hydrolysis, however, has only been proved in cases where water was added to solid calcium phosphate, although it has often been assumed to proceed in the same manner in solutions containing lime. Lorah (15) has shown that even a phosphate as basic as $Ca_3(PO_4)_2.Ca(OH)_2$ will absorb calcium hydroxide from solutions containing as little as 0.02 gram per liter. Since clarified juice contains far more lime than this, absorption of lime is more probable than re-solution of phosphate, as the mechanism by which the calcium content of the precipitate is increased.

A slightly different explanation has been offered by Holt (12), and accepted by Behne (2) and others. This is that $CaHPO_4$ is first precipitated, followed by the much slower precipitation of more basic calcium phosphate. The latter, being much less soluble, reduces the concentration of the solution so that it is no longer saturated with respect to $CaHPO_4$, which then dissolves. This is quite certainly correct whenever $CaHPO_4$ is present in the precipitate. However, microscopic examination shows that above pH 6 there is practically no di-phosphate present (7). At the much higher pH of clarified cane juice, precipitation and subsequent solution of $CaHPO_4$ is either completely absent, or so small as to have no noticeable effect.

The sharp drop in pH which is noticed after heating limed juice may be due to a very different effect. The calcium phosphate precipitate behaves like a "polyolated" complex (14), similar to those investigated by Thomas (19). These substances contain doubly bound hydroxyl ("ol") groups, which, on heating, are converted to doubly bound oxygen ("oxo") groups, with liberation of hydrogen ion. That this actually happens is shown by the fact that heating causes the electric charge (measured, as is the pH, after again cooling) to become more negative. With either re-solution of H_3PO_4 or absorption of $Ca(OH)_2$, one would expect

the charge to become more positive, whereas loss of positively charged hydrogen ion would give the observed result.

Reactions involving calcium phosphate are not, of course, the only cause of the constantly increasing acidity of clarified juice. Cook (16) has shown that prolonged boiling of sugar solutions causes a large drop in pH. This is due, at least in part, to decomposition and oxidation of the reducing sugars formed by inversion, although the possibility that the inversion process itself may be partly responsible has not been disproved.

III. *The Calcium Content of Clarified Juice:*

The high concentration of calcium remaining after precipitation in cane products, as compared with precipitation in water solution, was ascribed by Farnell (7) to the fact that "some of the lime is held in solution as the calcium salts of various natural cane juice acids." This can only be true of a portion of the original calcium in the juice, except when the titratable acidity is greater than the amount of phosphate, a most unusual case. (But this was the case in Bond's experiments with organic acids.) In practically all samples of cane juice the total acid is less than equivalent to the phosphate concentration; all the acid may be considered to be phosphoric, so that it is not necessary to neutralize other acids before precipitating calcium phosphate.

Similar large amounts of calcium in solution were noted by Behne (2) in the presence of dissolved calcium sulfate. There were 470 p.p.m. of CaO present before the addition of lime, whereas only about 120 p.p.m. were present when precipitation started in the absence of calcium sulfate.

The explanation is quite simple. The precipitation of calcium phosphate is dependent largely on pH, due to the effect on the ionization of phosphoric acid; the calcium concentration is less important. Thus the original high calcium concentration is not greatly decreased as the pH is raised by the addition of lime. In other words, when a neutral calcium salt is present in a phosphate solution, and lime is added, the calcium content of the solution increases (or decreases) roughly by the same amount as though the original calcium concentration had been zero, since the change in the composition of the precipitate is not sufficient to have any large effect. These conditions are fulfilled by cane juice, which always contains a considerable amount of calcium. Only a fraction of this original calcium can be precipitated as calcium phosphate by the addition of lime.

The fact that, as more lime is added, the excess in solution is smaller, that is, more lime is precipitated than in the absence of $CaSO_4$, is attributed by Behne to precipitation of $CaSO_4$. Inspection of his Fig. 8, however, shows that precipitation of sulfate is within the experimental error (up to the addition of three equivalents of CaO). Actually, the precipitated calcium phosphate is more basic in the presence of the large calcium concentration, and more calcium is removed from solution for this reason.

The composition of the precipitate will depend largely on the composition of the solution after addition of the lime, but before precipitation of calcium phosphate, if we may thus divide the reaction for purposes of explanation. For instance, if, after adding lime, there are 0.50 gr. CaO per liter in a water solution, and 0.70 gr.

CaO per liter in the juice, and 0.49 gr. precipitate from each, then only 0.01 gr. remains in the water solution, while 0.21 gr. remains in the juice. The difference in lime content is much more striking after precipitation than before.

It cannot be too strongly emphasized that the statements in the preceding paragraph are true in regard to the immediate precipitate only, and do not at all apply to the conditions at an equilibrium which might eventually be reached. As far as equilibrium is concerned, the lime concentration before precipitation has nothing to do with the case, only the final concentration being of importance.

The original lime content, however, is not the only cause of the high lime concentration. Above pH 7, the precipitation of magnesium hydroxide is important. For every equivalent of magnesia which precipitates, an equivalent of lime must go into solution, if the pH is to remain constant. The data of Bond show that in some cases, between pH 7.5 and 8.5, the increase in calcium in the juice is practically equivalent to the decrease in magnesium. This factor alone, according to these figures, can account for as much as 0.14 gr. CaO per liter in the clarified juice, as compared with a total CaO content of 0.2-0.4 gr. per liter.

In addition, the effective concentration of calcium ion is much smaller in juice than in a water solution. The ionic strength of a typical filtered clarified juice was calculated to be about 0.15. This corresponds to a calcium ion activity coefficient of about 0.25 (16); the calcium has only one fourth the effect that the same concentration would have in very dilute solution. Even a water solution containing precipitated calcium phosphate is not very dilute as far as activities are concerned, and the activity coefficient of the calcium might be as low as 0.8. This alone would lead one to expect the calcium concentration to be three times as large in clarified juice as in water solution.

Summary:

1. Calcium phosphate as precipitated by liming cane juice is not a definite compound.

2. After precipitation, the calcium content of the precipitate is increased by absorption of calcium hydroxide from the juice.

3. When the juice and precipitate are heated, the pH drops, due to oxolation of the precipitate.

4. Three major reasons for the high calcium content of clarified juice are: (*a*) the original calcium concentration; (*b*) replacement of precipitated magnesia by lime; and (*c*) the reduced activity of the calcium ion.

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Disease Symptoms in Lettuce and Celtuce, Caused by the Bean Leaf Hopper *Empoasca Solana* Del.

By J. P. Martin and C. E. Pemberton

The bean leaf hopper, Empoasca solana, *has been found to cause severe damage to lettuce and celtuce in Hawaii. Affected plants exhibit a yellowing followed by a chlorosis of the tips of the older leaves. In advanced stages the tissues become brown and die resulting in serious economic losses.*

The results from controlled cage experiments proved that this insect is the cause of the damage and that the degree of injury varies directly with the number of hoppers per plant.

During March 1942 a disease affecting lettuce, *Lactuca sativa,* was called to our attention by the geneticists of this Station, and as the hotter and drier season advanced the injury became more pronounced. In a number of localities the damage was severe. Pathological symptoms similar to those on lettuce were also observed in various gardens on celtuce or asparagus lettuce, *Lactuca sativa* var. *asparagina,* and endive, *Cichorium Endivia.* From our field observations it was evident that some varieties of lettuce were much more tolerant to the injury than others; the varieties New York 12, and Imperial 44 and 847 were severely affected while the green Mignonette variety was only moderately affected.

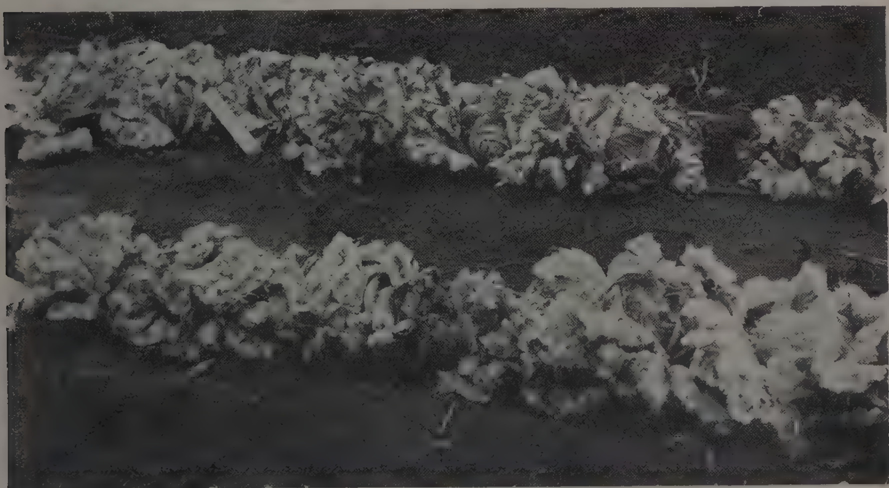


Fig. 1. Injury to field lettuce (New York 12) caused by the bean leaf hopper, *Empoasca solana.*

Disease Symptoms

The early symptoms are a yellowing followed by a chlorosis of the tips of the older leaves (Figs. 1, 2 and 3). When the injury is moderate the chlorosis is con-

Fig. 2. Showing degrees of injury to lettuce caused by the leaf hopper, *E. solana.* Left, injury moderate; center, injury moderate to severe; right, injury severe. Note burning and dead tissue on older leaves.

Fig. 3. Leaf hopper injury to lettuce leaves (Imperial 44). Left, injury moderate; right, injury severe. Note extent of chlorosis and dead marginal leaf tissue.

fined largely to the tips of the leaves but when the injury is severe the chlorosis includes the major portion of the leaf, as shown in Fig. 3. The affected leaf tissues, depending on the degree of injury, become brown and die, thus resembling an acute case of physiological tipburn which results from excessive transpiration. In the case of the latter the mesophyll tissues between the veins are the first to die while with this hopper-induced disease the veins are apparently affected first followed by the death of the mesophyll. These differences are used to differentiate tipburn and hopperburn in potatoes, a number of legumes and other plants.

Diseased plants are greatly retarded in growth and exhibit a marked curling of the leaves. In the advanced stages of the disease the necrotic or dead tissue of the tips and margins of the leaves is very conspicuous and many of the plants so affected cannot be marketed and frequently die.

Experimental Studies Pertaining to the Cause of the Disease

In some respects the symptoms were similar to those described for certain nutritional deficiencies in lettuce and for this reason Experiment 1 was carried out. Since the bean leaf hopper, *Empoasca solana,* was extremely common on affected lettuce and celtuce plants, and since the nature of the injury was similar to that caused by insects of the same genus on other plants, Experiments 2, 3 and 4 were conducted.

Experiment 1: The soil, in which young lettuce and plants manifesting early symptoms of the disease were growing, was treated with an A-Z fertilizer which carries the elements essential for plant growth including the trace elements such as copper, boron, zinc, and manganese. Nitrogen, potassium, and phosphorus were applied in sufficient quantities so as to eliminate the possibility that anyone of these would be the limiting factor for normal growth. The affected plants in the treated soil failed to recover under field conditions, in fact the severity of the trouble increased with the advent of hotter and drier weather. The results from this preliminary test indicated that the cause of the disease was not directly nutritional in nature.

Experiment 2: On May 5, 1942 a large glass chimney was placed over each of 12 young celtuce plants, Fig. 4. The first 4 plants received the A-Z fertilizer (described in Experiment 1) and the next four plants remained as checks. The plants in these 8 cages were sprayed with nicotine sulphate in order to eliminate all insects. In the remaining 4 cages large numbers of the leaf hoppers were introduced. Three days later definite injury was evident on the plants in the cages heavily infested with leaf hoppers. On May 11, 1942 or 6 days after the hoppers were introduced, the older leaves of the plants were severely "burned" and the plants in general were badly stunted. On the seventh day the cages were removed and the plants were photographed, Fig. 5. The injury at this time corresponded to the advanced stages of the disease where necrosis has developed. The 8 plants without insects were normal and made an excellent growth as shown in Fig. 5.

Experiment 3: The 8 plants which were not infested with leaf hoppers in Experiment 2 were again caged immediately after the plants were photographed. Three of the plants served as checks and the remaining five were infested with 10,

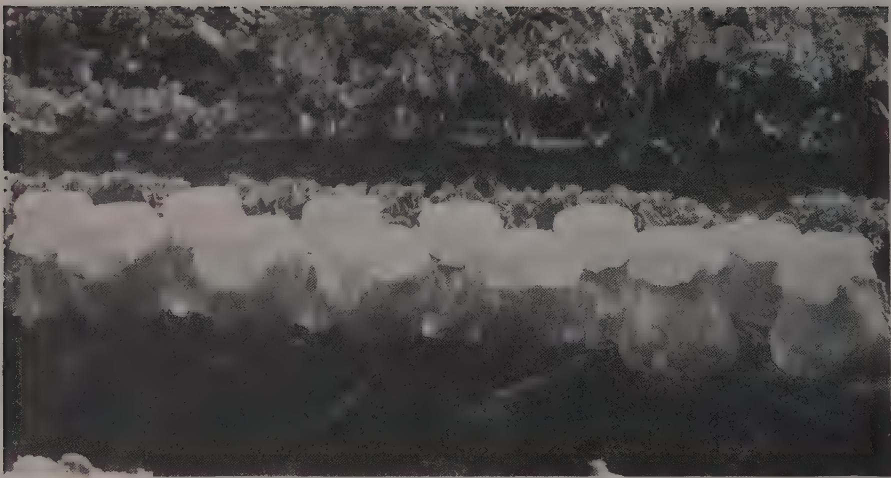


Fig. 4. Caged lettuce plants used in Experiment 2. The four plants on the right were infested with large numbers of leaf hoppers while the remaining eight plants served as checks and were again used in Experiment 3.

Fig. 5. The four celtuce plants, between the stakes, show severe hopper injury after the insects were allowed to feed on the plants for seven days. The check plants on the left remained normal and made an excellent growth in the absence of leaf hoppers.

19, 41, 80, and 116 leaf hoppers respectively. The object of this test was to study the degree of injury in relation to insect numbers.

At the end of 2 days definite leaf injury was noted on the plant infested with 116 hoppers and as the experiment continued the injury became more severe. Moderate-to-severe injury was observed on the plant infested with 80 hoppers on the 7th day while on the 11th day the injury was severe. The early symptoms of the disease were noted on the plant with 41 hoppers at the end of 7 days and on the 11th day the injury was moderate. The plant with 19 hoppers manifested a few chlorotic leaf tips on the 11th day. The plant with 10 hoppers developed no symptoms of disease on the 11th day when the test was photographed in the field, Fig. 6. At this time the plants were removed from the field and photographed (Fig. 7).

This test showed that the degree of injury was directly correlated with the number of hoppers per plant.

Experiment 4: One young lettuce plant of the variety Imperial 44 was transplanted on May 8, 1942 to each of twelve 12-inch concrete pots and fertilized with a fertilizer carrying nitrogen, potassium, and phosphorus. The first 5 plants were left uncovered while the remaining 7 were covered with a glass chimney.

On May fifteenth, 10, 21, 40, 80, and 138 leaf hoppers were added to five of the individual caged plants respectively—the object being to study the degree of injury by insect numbers, as in Experiment 3.

The results of this test were identical with those of Experiment 3. At the end of three days the injury on the lettuce plant with 138 hoppers was severe and only moderate on the plant with 80 insects; during the next 5 days the degree of injury on both plants became more severe. The plant with 40 hoppers showed moderate symptoms of the disease at the end of 7 days; the one with 21 hoppers exhibited only a few symptoms at the end of 10 days, while the plant with 10 hoppers manifested no visible symptoms. The insects failed to build up a population on the caged lettuce plants and at the end of two weeks most of them had died and thereafter the caged plants showed a marked recovery. The two check plants (caged) exhibited no disease symptoms and made a normal growth.

Within three weeks the check plants, which were exposed to natural insect attack, developed definite symptoms of the disease and leaf hoppers were numerous on the plants.

Discussion

Within recent years a number of major plant diseases caused by insects injecting toxic substances into plants during their feeding have been studied in several countries. This type of disease differs from a virus disease in that: the phytotoxic substance is not reproductive within the plant; the affected plants frequently recover; the degree of injury varies directly with the insect population; the disease is not transmitted by plant parts (budding or grafting); and the control of the disease varies directly with the control of the insect. Some of the diseases in this group are: froghopper blight of sugar cane, mealy-bug wilt of pineapples, hopperburn of potatoes and other plants, and psyllid yellows of potatoes. Insects causing these diseases are known as toxicogenic insects, and in general the symptoms of the diseases are: a yellowing or chlorosis of the leaves, a retardation of growth,

Fig. 6. The first five plants (Experiment 3) on the left show the progressive degree of injury, on the eleventh day, from 10, 19, 41, 80, and 116 leaf hoppers respectively. The check or leaf hopper-free plants on the right were normal.

Fig. 7. The celtuce plants shown in Fig. 6 were removed from the field and again photographed in order to show more clearly that the degree of injury was directly correlated with the number of hoppers per plant. The plant on the left was a check while the others were infested with 10, 19, 41, 80, and 116 leaf hoppers respectively. The plants, upon their removal from the field had wilted slightly before being photographed.

excessive leaf curling, and a burning of the leaf tips followed by necrosis and often the death of the plants.

The potato leaf hopper, *Empoasca fabae* Harris, which is closely related to the bean leaf hopper, causes severe damage on beans, clover, alfalfa, cowpeas, soybeans and other legumes, and potatoes in the Eastern United States. The insect usually penetrates the vascular tissues with its needlelike mandibles, feeds on the phloem elements and causes a disorganization of cells somewhat removed from the feeding puncture; a clogging of the phloem has also been reported—all of which greatly interferes with the normal physiology of the plant.

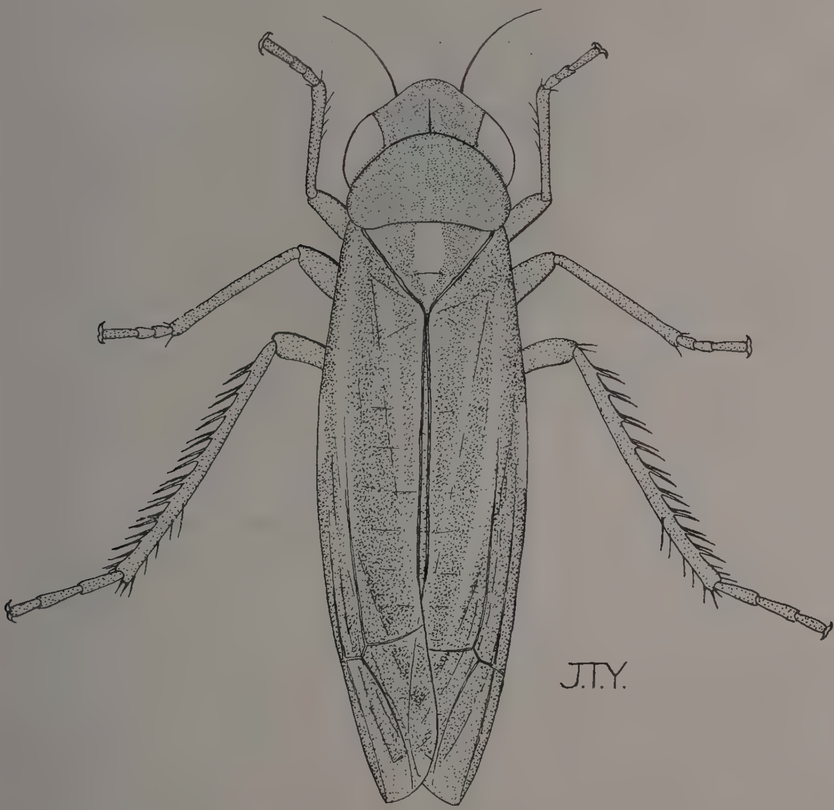


Fig. 8. The bean leaf hopper (*Empoasca solana*). Female. Color: Bright green. ×35.

The bean leaf hopper (Fig. 8) is not of Hawaiian origin. It was originally described from material collected in Louisiana. It may be considered a recent immigrant to Hawaii. The first specimen was collected on spiny amaranth on Oahu in 1918, and during ensuing years it became so common on this plant that it was referred to by entomologists in Hawaii as the amaranth Jassid. Other plants known as hosts in Hawaii are watermelon, castor bean, various solanaceous plants and garden beans of many sorts. It was not until 1937 that beans were reported to

be heavily damaged by this hopper. Of all the varieties of beans grown in vegetable gardens in Hawaii today, the cowpea appears to be the preferred host.

The first reference to *Empoasca solana* as the active, causative agent of hopperburn on potatoes, watermelon and castor bean in Hawaii, is by Walter Carter.*

Summary

A disease in lettuce and celtuce caused by the leaf hopper, *Empoasca solana,* is described. Symptoms of the disease have also been recorded on endive. This is apparently the first record of this disease occurring on these plants in the Territory.

From the experimental studies conducted we may conclude that: the injury results from a toxic secretion of the leaf hopper injected into the leaf during its feeding; the degree of injury varies directly with the insect population; affected plants recover when the insects are removed; and the control of the disease will be in direct proportion to the control of the leaf hopper. In the future this disease may be referred to as hopperburn.

* Carter, Walter, 1936. Insects and Plant Diseases. Proc. Haw. Ent. Soc., IX, No. 2, pp. 159-170.

A Study of Optimum Crop Length

By R. J. Borden and F. C. Denison

Monthly rates of growth of sugar cane were differentially influenced by the month of starting the crops. Crops which were started nearer the middle of the year made a uniform monthly elongation thereafter, whereas winter-started crops showed subsequent seasonal effects which appear as both high and low peaks on their growth curves.

Growth rates for stalks of all ages were highest between July and October. Age effects, regardless of seasonal effects, showed up as an almost straight-line reduction in elongation between 8 and 25 months.

Numbers of millable stalks at harvest were not proved to be influenced by month of start or age at harvest. Average length and weight of stalks were influenced by the changing status of the stalk population.

Crusher juice analyses were influenced by the age at harvest: the per cent P_2O_5 increased with an increase in age, and both N and K_2O showed decreasing concentrations as crops became older at harvest.

Highly significant effects from both the month of start and the age at harvest were measured on yields. Interactions were not generally significant as they were apparently dominated by the age effects. Crops started in mid-season gave yields superior to those starting earlier or later, regardless of their age at harvest. The rate at which cane was produced by plant crops fell off sharply after 22 months, but the ratoons continued to make cane at a uniform rate up to 25 months. Although cane quality continued to improve with age up to 25 months, sugar yields followed the trends in cane yields, and our final answer shows that the optimum age to harvest H 109 was at 22 months for plant cane and at 25 months for ratoons, regardless of the time of starting the crop.

Begun in August 1936 and completed 5½ years later in February 1942, a study of a growing cane crop in its actual field environment* has contributed facts and verified opinions to give us a still better understanding of the sugar cane crop. As originally outlined, our objective was a study designed to furnish specific information concerning: (*a*) the rate of growth of sugar cane at its various stages of development in different months of the year, and (*b*) the optimum age to harvest H 109 cane started at different times.

Plan:

The field area selected consisted of 24 sections of 18 lines each in Waipio Field 37; each of these sections was divided into 8 two-line plots, plus an extra guard line at top and bottom. One section was planted each month for 24 consecutive months. Superphosphate carrying 100 pounds P_2O_5 per acre was applied with

* Waipio Expt. 101AH.

the seed and efforts were made to insure a full stand in each line. No phosphate fertilizer was given to the ratoon crops. Adequate irrigation was given in each section throughout the crop; no attempt was made to "dry-off" before each harvest. Fertilizer was applied on each section according to a definite and similar schedule, *i.e.*, (1) 30 pounds N at 1 month, (2) 50 pounds N at 3 months; (3) 50 pounds N at 5 months; (4) 50 pounds N at 7 months, and (5) 80 pounds N and 74 pounds K_2O at 10 months.

In each section of the plant crop, starting at the time when the basal dry-leaf internodes of canes were clearly visible, 50 adjacent stalks in the 16th row were tagged for subsequent monthly growth measurements. For the ratoon crop, 40 stalks—5 in each of the 8 groups which were started in the same month—were measured for their average monthly elongation. Replacements for many stalks which tasseled or died were necessary to keep the total number of living stalks being measured monthly at not less than 30 in each group.

During harvesting of the plant cane at ages from 18 to 25 months, measurements, weights, and other harvest data were secured from all cane cut from the inside 40 feet of rows Nos. 3, 5, 7, 9, 11, 13, 15 and 17 respectively. As the plots of plant cane were harvested, they were immediately ratooned so that subsequently we were also able to secure similar measurements and yield data in the ratoon crops from rows Nos. 2, 4, 6, 8, 10, 12, 14 and 16 respectively. Treatment of ratoons was as similar as possible to that of the plant crops. Minor deviations from these specific plans of procedure were sometimes necessary, but a careful study of the effects from these deviations ultimately indicated that they had contributed only an insignificant amount to the total variations measured.

Presentation of results:

In earlier progress reports on this study, we calculated and presented "running averages" for the various measurements made, in order to smooth out the extreme variability of the field data which were secured. Since the data have been collected by many individuals* and from very small areas of canes which had received normal field practice, it is only natural that some wide variability was encountered. In this final report, since the tabulated figures are so voluminous, we have presented most of the data graphically, without "smoothing," so that the reader may if he wishes make further use of the specific values shown on the graphs. In their interpretation, however, the trends shown by the graphs should receive more consideration than the actual values themselves, and abrupt deviations from these trends may be considered as most likely due to the experimental errors involved.

Monthly rates of growth (Fig. 1:—12 graphs):

In these graphs we have recorded the average monthly increase in stalk elongation made by comparable groups of selected canes, 6 to 8 months old and up to 25 months of age, in crops started in each month of two consecutive years (the actual

* All assistant-agriculturists-in-training who have been at the Waipio Substation since August 1936 have assisted in the planting, fertilizing, measuring, sampling, and harvesting operations involved in this investigation. Their painstaking and valuable assistance is hereby acknowledged.

month in which the respective ages were attained is also indicated). Both plant and ratoon crop growth records are plotted.

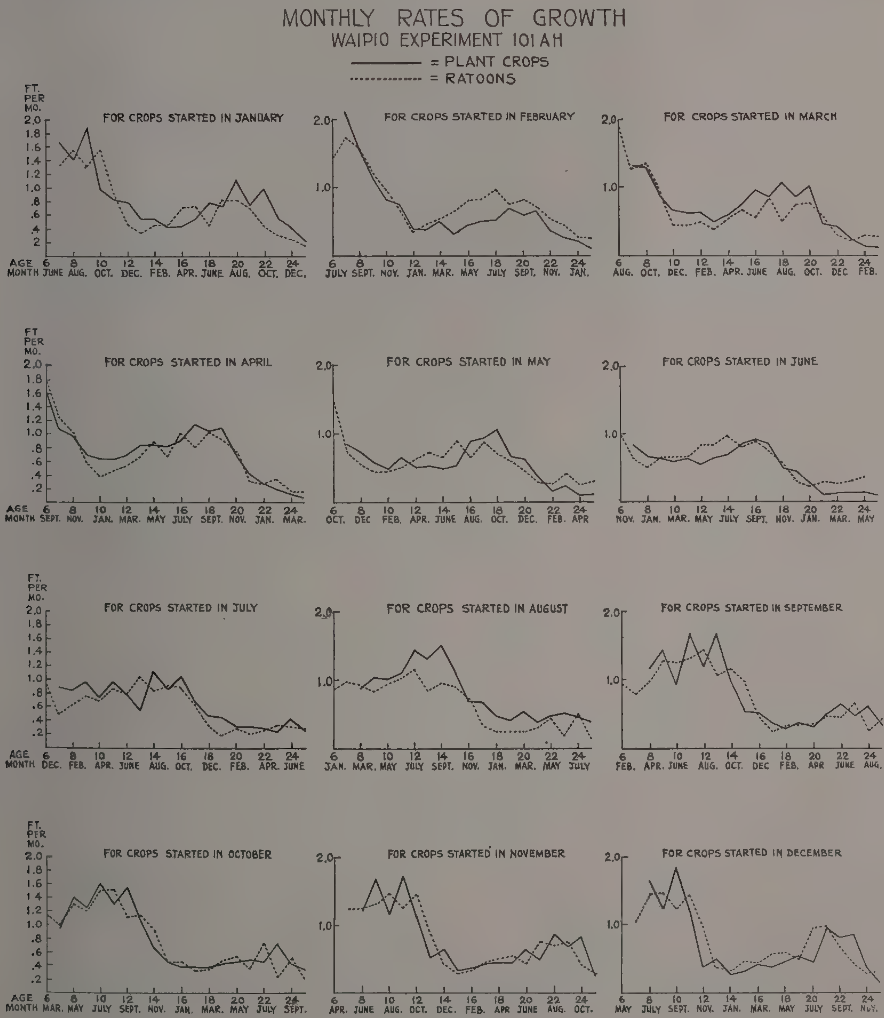
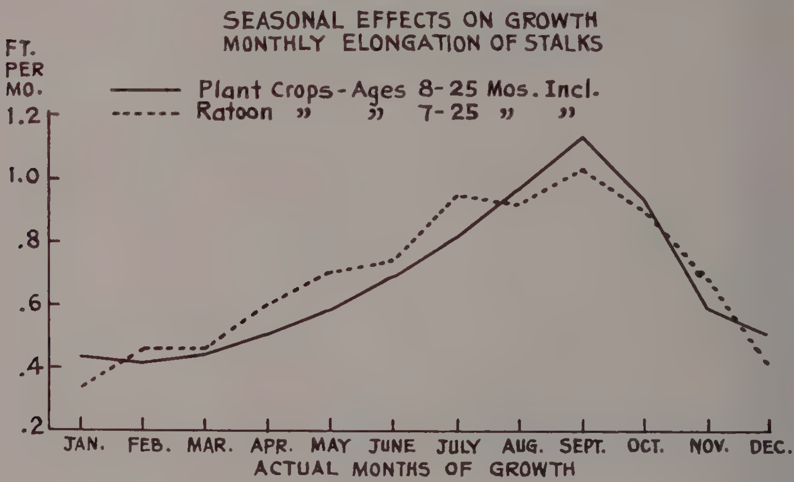


Fig. 1

Striking similarity of the plant and ratoon crop elongations is apparent. This would indicate that the growth response of healthy, non-tasseled stalks from plant and from ratoon crops has not been significantly different.

Rates of elongation for crops started in different seasons show quite different patterns. For instance: (*a*) The growth rate for crops started in January was apparently at its high point in late fall when the cane was 8 to 10 months old; thereafter it was drastically checked by winter conditions. It recovered and attained a second but greatly reduced peak during its second summer at about 20 months

of age. (*b*) Cane started in March was not growing as fast at 8 months in October as the 8-month old cane from the January starts; the first winter growth rates however were not materially different, and the second-season growth peak occurred at about the same time of year but when this crop was about 18 months old. (*c*) For May-started crops, the initial first-season growth peak noted in earlier started crops is missing, and the rate of growth, though much reduced, is seen to be without any great fluctuation for nearly 18 months; the second-season growth peak, if we may conjecture it, has apparently moved farther to the left and was effective before the



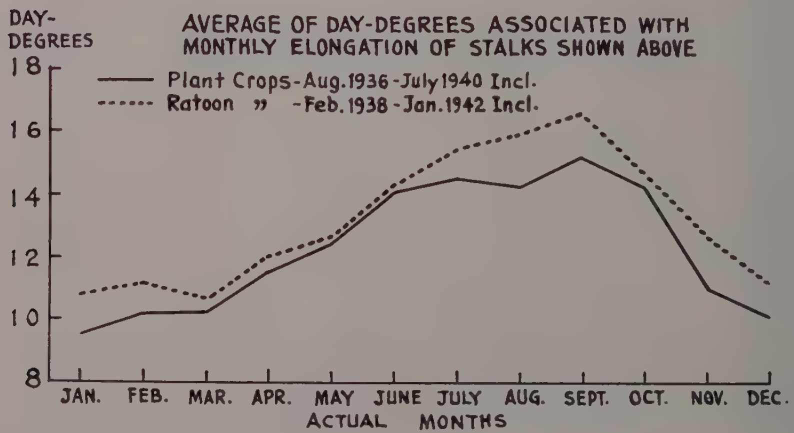


Fig. 2

crop was 18 months old. (*d*) The July-started crops had quite similar growth rates to those started in May; again the peak of second-season growth has moved farther to the left and indicates an effect on still younger cane; furthermore the

growth rate for cane older than 16–17 months stays at a very low level. (*e*) Crops started in September reached their highest growth rate about 12 months later; winter weather then cut this rate to about one third and, after the canes were 15 months old, they averaged less than one-half foot of new growth per month. (*f*) The curve for crops started in November approaches that for January-started crops, showing the same excellent early growth rate checked by the winter, but the second-season peak of growth coming slightly later, at 22 to 23 months.

These representative growth patterns which we have measured are different chiefly in the range between their high and their low points. Crops started in mid-season show a more uniform growth rate throughout their critical growth periods, whereas both the early- and late-started crops show more definite seasonal effects, with growth rates at some seasons more than three times those at others. Whether these facts are contributory causes to cane quality is not known for certain, but it is an interesting coincidence that the yield-per-cent cane from these crops which were started in mid-season was generally superior (See Fig. 11).

Seasonal effects on growth (Fig. 2):

To better visualize the effects on the average monthly stalk elongation in a crop of cane carrying a mixed millable-stalk population of different ages, we have prepared Fig. 2. This is based on measurements from 30 to 50 stalks of plant cane or 20 to 40 ratoon stalks, of each age from 7 or 8 to 25 months inclusive, taken in each month of the year during two consecutive years; thus each point on this graph represents a measurement of not less than 1080 stalks from plant crops and 720 stalks from ratoons.

The high growth value of the months of July to October verifies our previously held opinion that the optimum H 109 cane growth is during these months. Similarly we have been aware of the low rate of growth which is usually made be-

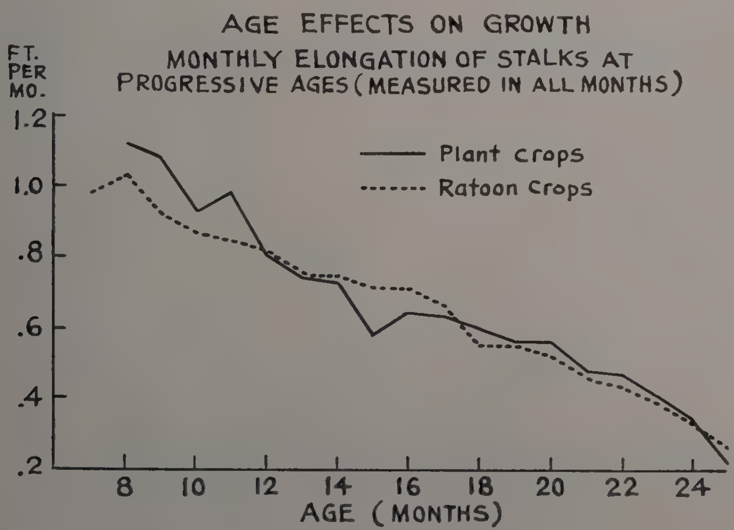


Fig. 3

tween December and March. Quantitatively, it is now convincingly seen that the value of the July-October growth rates is more than twice that of the December-March rates.

A graphical presentation of the average day-degrees associated with these seasonal growth measurements is seen to have a fairly good relationship, and again reflects the positive effects of maximum temperatures on cane growth.

Age effects on growth (Fig. 3):

Growth measurements on both plant and ratoon crops were similarly affected by the age of stalks, and Fig. 3 shows an almost straight-line reduction in monthly stalk elongation for canes between 8 and 25 months of age. Data for this graph came from stalk measurements made in every month for 24 consecutive months on cane at all ages indicated; hence each point is an average of not less than 700 measurements on plant cane or 480 on ratoons.

Combined age and seasonal effects (Fig. 4):

A statistical study of the relationship between age effect and seasonal effect upon these growth measurements shows that both of these factors probably acted

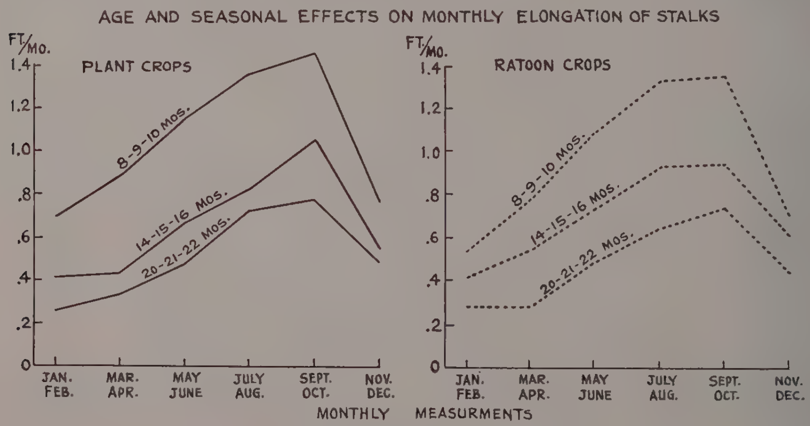


Fig. 4

independently of each other, *i.e.,* their interaction was dominated by their separate influences. The magnitude of their effect was, however, somewhat different, and this is shown by Fig. 4.* For instance, plant canes of all ages grew twice as fast in July-August as in January-February but the actual July-August elongation for canes 20–22 months old was only half that of canes 8–10 months of age. Also, although the maximum growth rate for cane of all ages came in September-October, this maximum for cane 20–22 months old was seldom as great as the minimum growth which was made by 8–10-month old cane during its winter season.

* Graphs for cane of ages 11–12–13, 17–18–19, and 23–24–25 months have been omitted for clarity; they fall intermediate between those for ages shown.

Stalk census at each harvest:

A census of the entire stalk population within a 40-foot section of cane row was made at each harvest. From Fig. 5 it would appear that the number of millable stalks per foot of row found in the plant crops was somewhat greater and also quite different from that of the ratoons. Seasonal effects on the plant cane crops

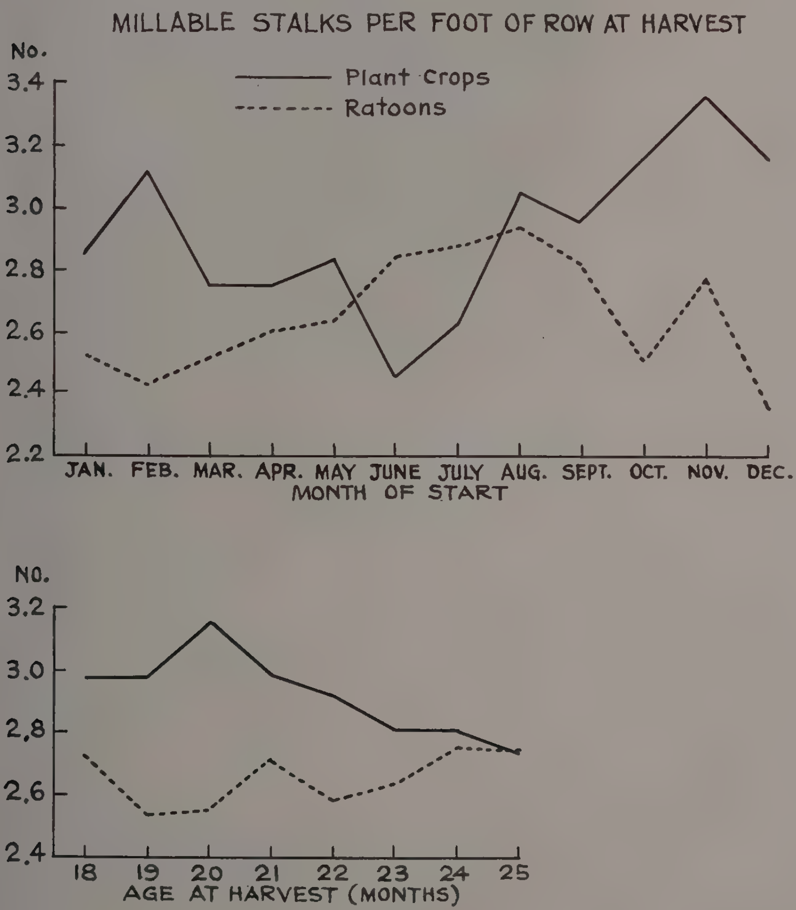


Fig. 5

indicated more millable stalks at harvest from cane planted in the August-to-February period than from March to July. However, this observation was not supported by the ratoon crops since they appear to have matured more stalks from the crops started in mid-summer.

The effect of age at harvest on the number of millable canes was also different for the plant and ratoon crops. In the plant crops there were definitely less millable canes harvested progressively after 20 months, whereas in the ratoons the trend appears to have been in the other direction. Thus it appears doubtful that

we can generalize with respect to the effect of age at harvest or of the month of starting on the number of millable stalks to be found at harvest.

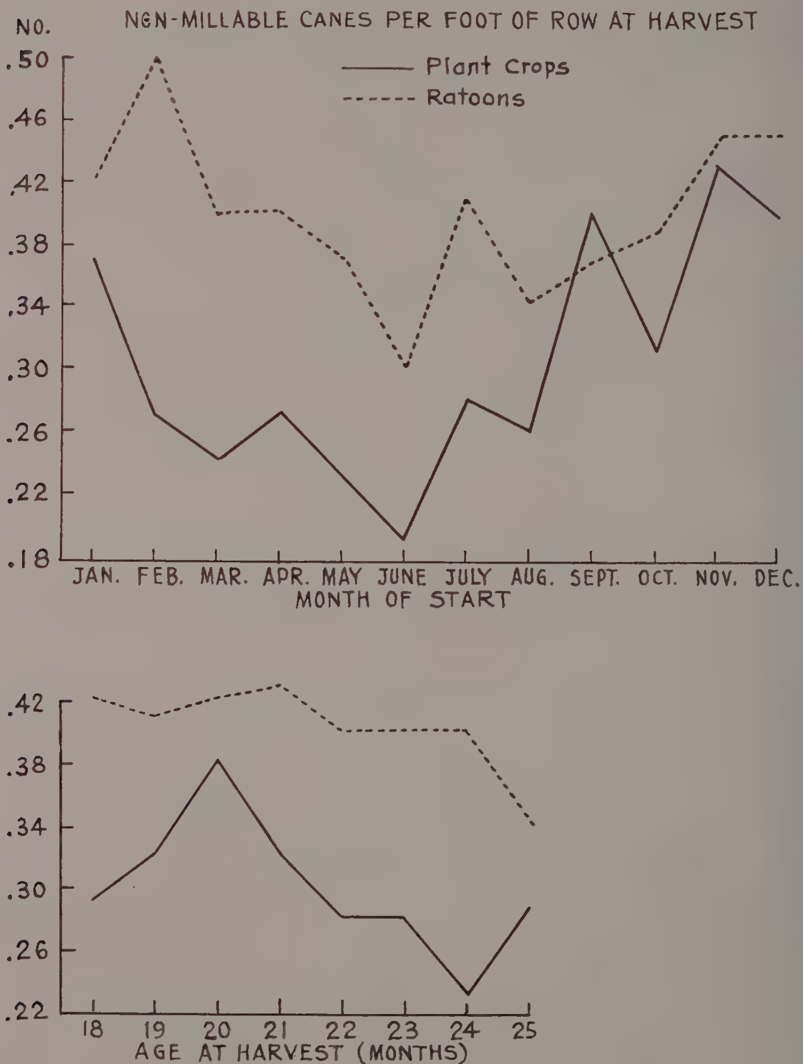


Fig. 6

In Fig. 6, it is clearly shown that the ratoon crops had many more non-millable stalks at harvest than the plant crops. Furthermore, we note more non-millable canes from crops started at the beginning and at the end of the year than from those which were started in mid-season. Perhaps also there is a reduction in the number of non-millable stalks which is an effect of an increase in age at harvest.

The number of dead stalks found in the ratoons was also greater than found in

the plant crops; it increased quite similarly with advanced age. The effect of month of start on dead canes at harvest was entirely dissimilar for the two crops studied; apparently the age at harvest was the more dominant factor (see Fig. 7).

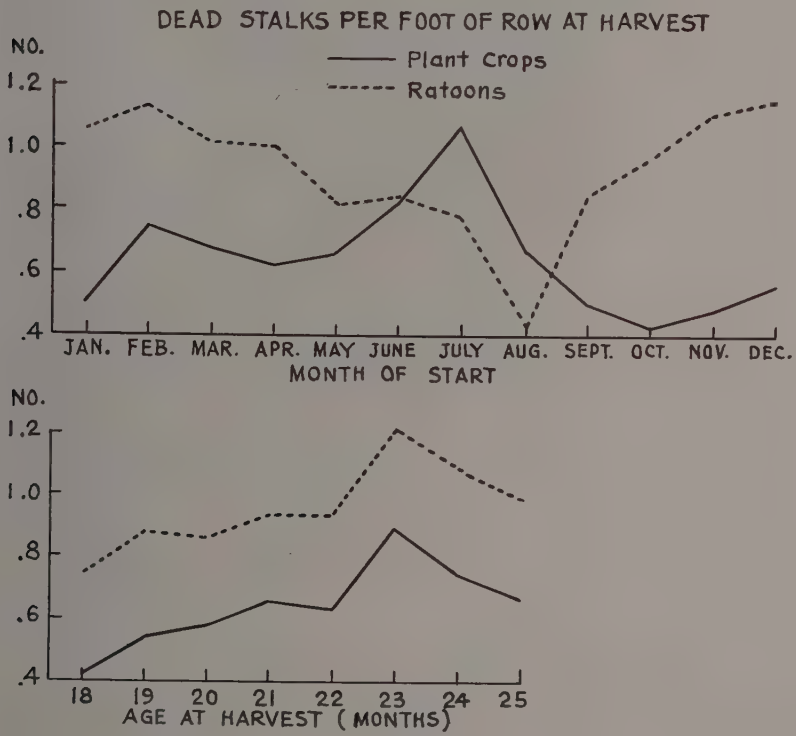


Fig. 7

Length and weight of millable stalks at harvest:

From Fig. 8, it is apparent that the millable stalks from the plant crops were slightly longer than those from the ratoons and, in general, longer stalks were harvested from crops which were started in the better growing months or mid-season.

The actual average length of all stalks milled at harvest increased with age, but was undoubtedly influenced by the changing status in the stalk population.

Millable stalks from the plant crop were heavier per foot of stalk than from the ratoons (see Fig. 9). Those from crops started earlier in the year were somewhat heavier than those which were started late. The effect of age at harvest was not entirely consistent on the two crops compared, although there seems to have been a falling-off in pounds-per-foot of stalk at the more advanced ages; this also is most likely an effect of the changing stalk population.

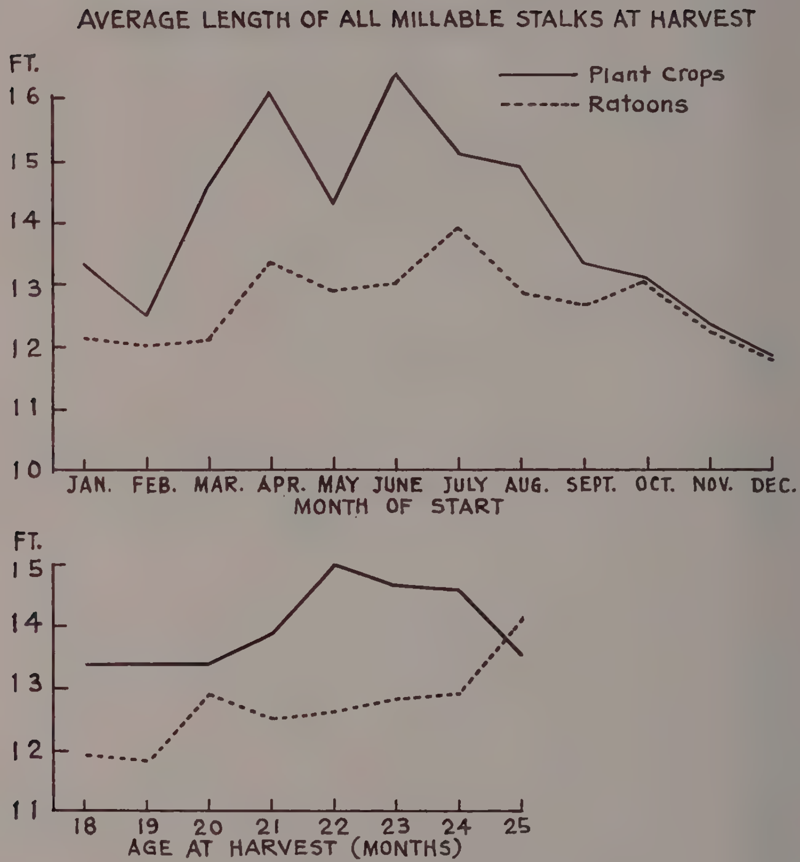


Fig. 8

Crusher juice analyses:

In addition to sugar and glucose analyses, crusher juices were analyzed for their percentages of nitrogen, phosphoric acid, and potash. These data are presented in Fig. 10.

It is quite apparent that these juice analyses have varied to a considerable extent, this in spite of the fact that the N, P, K, fertilization has been similar (except for phosphate) and the soil of the entire area was not too heterogeneous.

Phosphate was supplied only for the plant crop; thus it is interesting to note that in general the ratoon crops had slightly higher concentrations of phosphates at harvest. Plant crops which were started late in the year had higher percentages of phosphate in their crusher juices than crops started earlier; juices from ratoon crops showed just the opposite effect from their time of start. In both crops, however, increasing concentrations of phosphate were found as the crops became older at harvest.

The percentages of potash in juice were higher in the plant crops. The influence from month of starting the crop was exceedingly variable, and followed quite dif-

ferent patterns in the plant and ratoon crops. The effect of increased age at harvest was to reduce the per cent K_2O, and this feature was common to both crops.

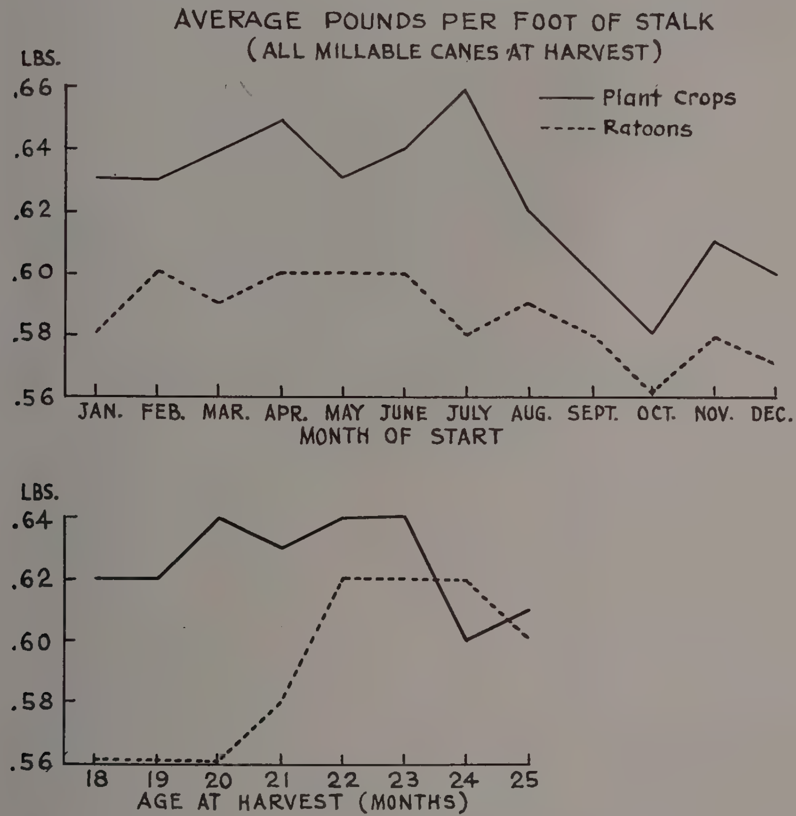


Fig. 9

Crusher juice concentrations of nitrogen were perhaps not greatly influenced by the month of start for either plant or ratoon crops, although there may be an indication of slightly higher nitrogen percentages from crops started in the better growing months. Age at harvest affects the per cent N in the same way as it does per cent K_2O, *i.e.*, a definite decrease in N with an increase in age. Thus it is seen that whereas the per cent P_2O_5 in the juice *increases*, the concentration of both N and K_2O *decreases* with advancing age at harvest.

Yields:

Although the data discussed above are of interest mainly in helping us to appreciate how the cane crop develops and responds to different seasonal and age effects, the actual "pay-off" for the planter comes only after all of these growth factors have been integrated and show their combined effects in the yield data.

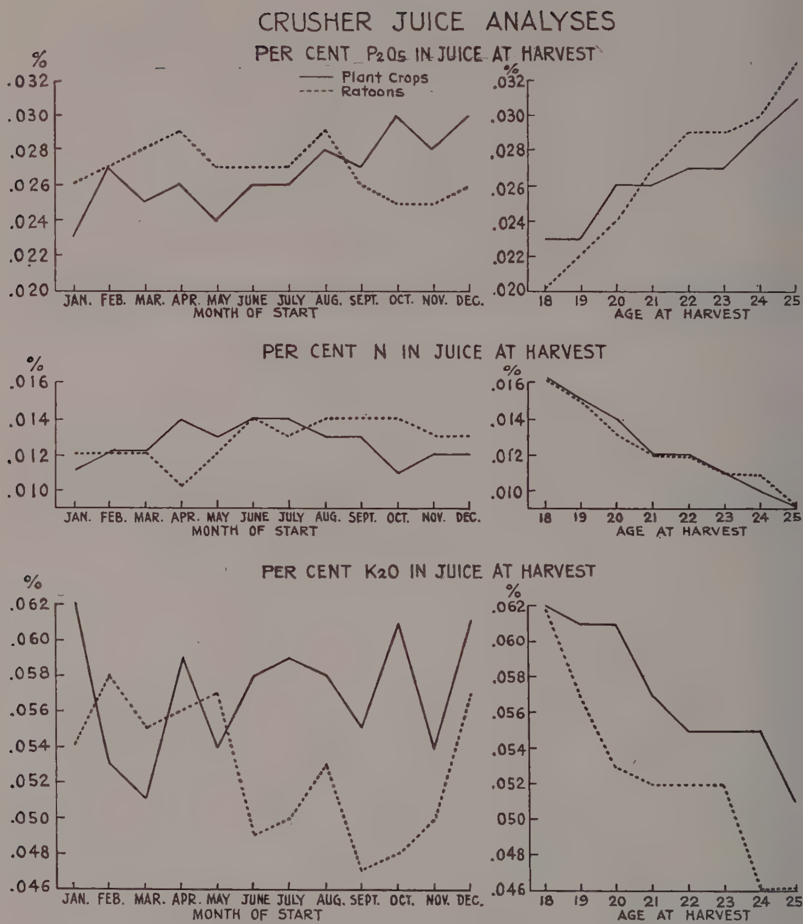


Fig. 10

TABLE I

SUMMARY OF YIELDS FROM PLANT AND RATOON CROPS

(1) Effects of Month of Start

Total plots	Month of start	TCA Plant crops	TCA Ratoon crops	Y%C Plant crops	Y%C Ratoon crops	TSA Plant crops	TSA Ratoon crops
16	Jan.	101	76	11.4	12.5	11.5	9.6
16	Feb.	105	75	11.1	11.8	11.4	8.6
16	Mar.	109	78	11.4	12.0	12.3	9.6
16	Apr.	121	88	11.1	12.6	13.5	11.2
16	May	110	89	12.2	12.4	13.1	11.2
16	June	113	97	12.5	13.1	14.1	12.9
16	July	112	99	12.5	13.4	13.7	13.3
16	Aug.	124	98	12.2	13.3	14.9	13.2
16	Sept.	103	91	12.6	13.3	13.0	12.1
16	Oct.	104	79	13.1	12.8	13.6	10.1
16	Nov.	108	85	11.9	12.5	12.7	10.6
16	Dec.	95	69	11.6	12.2	11.0	8.3
Minimum difference required for significance		15	12	.6	.5	1.9	1.6

(2) Effects of Age at Harvest

Total plots	Age at harvest	TCA Plant crops	TCA Ratoon crops	Y%C Plant crops	Y%C Ratoon crops	TSA Plant crops	TSA Ratoon crops
24	18 Mos.	106	79	10.8	11.6	11.4	9.2
24	19 "	106	73	11.0	11.9	11.6	8.7
24	20 "	117	78	11.4	12.2	13.3	9.5
24	21 "	111	83	11.7	12.7	12.8	10.5
24	22 "	120	87	12.1	12.9	14.5	11.2
24	23 "	112	89	12.4	12.9	13.8	11.7
24	24 "	103	94	12.7	13.3	13.1	12.7
24	25 "	95	98	13.5	13.8	12.8	13.5
Minimum difference required for significance		13	10	.5	.4	1.6	1.3

In this study cane yields were secured by weighing all millable cane from an inside 40-foot row of cane. After weighing, this cane was run through a 3-roller mill and its crusher juice analyzed for several constituents. Data have been converted to the usual bases and are offered in Table I and in Figs. 11, 12, 13 and 14; combined effects are given in condensed tabular form in Tables II, III, and IV.

Subjected to statistical analyses, the original data supply the following information for further discussion.

ANALYSIS OF VARIANCE
FOR AGE AT HARVEST AND MONTH OF START

Source of variation	Degrees of freedom	Mean squares or variance: For TCA on plant crops	For TCA on ratoons	For Y%C on plant crops	For Y%C on ratoons	For TSA on plant crops	For TSA on ratoons
Age at harvest	7	1601†	1702†	20.76†	12.15†	25.54†	69.99†
Month of start	11	1042*	1588†	6.69†	4.38†	22.04†	47.10†
Interaction	77	334	443	1.54†	2.04†	4.11	11.75†
Error	96	483	316	.74	.55	7.79	5.36
Total	191						
General Average		109	85	12.0	12.7	12.9	10.9
Coefficient of Variation		20.2%	20.9%	7.2%	5.8%	21.6%	21.3%

* Exceeds P = .05 or odds of 19 to 1.
† Exceeds P = .01 or odds of 99 to 1.

Thus the several effects of both age at harvest and months of starting the crop are seen to be highly significant, with the age effect dominating, especially on the Y%C. A few interactions, although significant with respect to error, are perhaps not significant with respect to either main factor separately; hence it is most likely that both of the main effects act independently and are perhaps not differentially influenced by each other. This contention is supported by the yield data which we have combined in condensed tables, No. II to IV which follow:

TABLE II

EFFECTS OF *TIME OF START* AND *AGE AT HARVEST* ON AVERAGE *TONS CANE PER ACRE* (TCA)

Months of start	For plant crops—ages at harvest					For ratoons—ages at harvest				
	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for months	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for months
Jan.-Feb.	96	110	113	95	103	71	78	72	82	76
Mar.-Apr.	110	121	137	95	115	70	70	83	110	83
May-June	118	125	114	89	111	77	81	101	114	93
July-Aug.	121	129	121	103	118	73	96	119	104	99
Sept.-Oct.	103	98	102	112	104	86	84	83	87	85
Nov.-Dec.	89	105	113	101	102	79	78	71	80	77
Avg. for Ages	106	114	116	99		76	81	88	96	

TABLE III

EFFECTS OF *TIME OF START* AND *AGE AT HARVEST* ON AVERAGE *YIELD PER CENT CANE* (Y%C)

Months of start	For plant crops—ages at harvest					For ratoons—ages at harvest				
	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for months	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for months
Jan.-Feb.	11.1	10.8	10.9	12.3	11.3	12.4	11.6	11.6	13.2	12.2
Mar.-Apr.	9.9	10.3	11.7	13.2	11.3	11.2	11.2	12.9	13.9	12.3
May-June	10.4	11.7	13.3	14.1	12.4	10.3	12.6	13.6	14.7	12.8
July-Aug.	10.6	12.0	13.2	13.6	12.3	11.7	13.3	14.1	14.3	13.4
Sept.-Oct.	11.9	12.7	13.5	13.4	12.8	12.5	13.4	13.2	13.1	13.1
Nov.-Dec.	11.7	11.9	11.1	12.5	11.7	12.7	12.6	11.9	12.2	12.4
Avg. for Ages	10.9	11.5	12.3	13.1		11.8	12.5	12.9	13.6	

TABLE IV

EFFECTS OF *TIME OF START* AND *AGE AT HARVEST* ON AVERAGE *TONS SUGAR PER ACRE* (TSA)

Months of start	For plant crops—ages at harvest						For ratoons—ages at harvest					
	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for mos.	Avg. TSA/mo.	18–19 mos.	20–21 mos.	22–23 mos.	24–25 mos.	Avg. for mos.	Avg. TSA/mo.
Jan.-Feb.	10.5	11.6	12.3	11.4	11.4	.54	8.7	8.5	8.3	10.9	9.1	.42
Mar.-Apr.	10.9	12.5	15.8	12.4	12.9	.60	7.7	7.8	10.7	15.3	10.4	.48
May-June	12.4	14.5	15.1	12.4	13.6	.64	8.0	10.0	13.7	16.6	12.1	.56
July-Aug.	12.8	15.1	15.6	13.9	14.3	.67	8.5	12.8	16.7	14.8	13.3	.62
Sept.-Oct.	12.2	12.4	13.8	15.1	13.3	.62	10.8	11.2	11.0	11.3	11.1	.52
Nov.-Dec.	10.4	12.3	12.5	12.5	11.9	.55	10.0	9.8	8.5	9.6	9.5	.44
Avg. for Ages	11.5	13.0	14.1	12.9			9.0	10.0	11.5	13.1		
Avg. TSA/Mo.	.62	.64	.63	.53			.49	.49	.51	.53		

Inspection of Fig. 11 clearly shows the higher yields of cane and of sugar, but the poorer quality (Y%C), from the plant crops. In general, both cane and sugar yields which came from crops started in mid-season were superior to those from

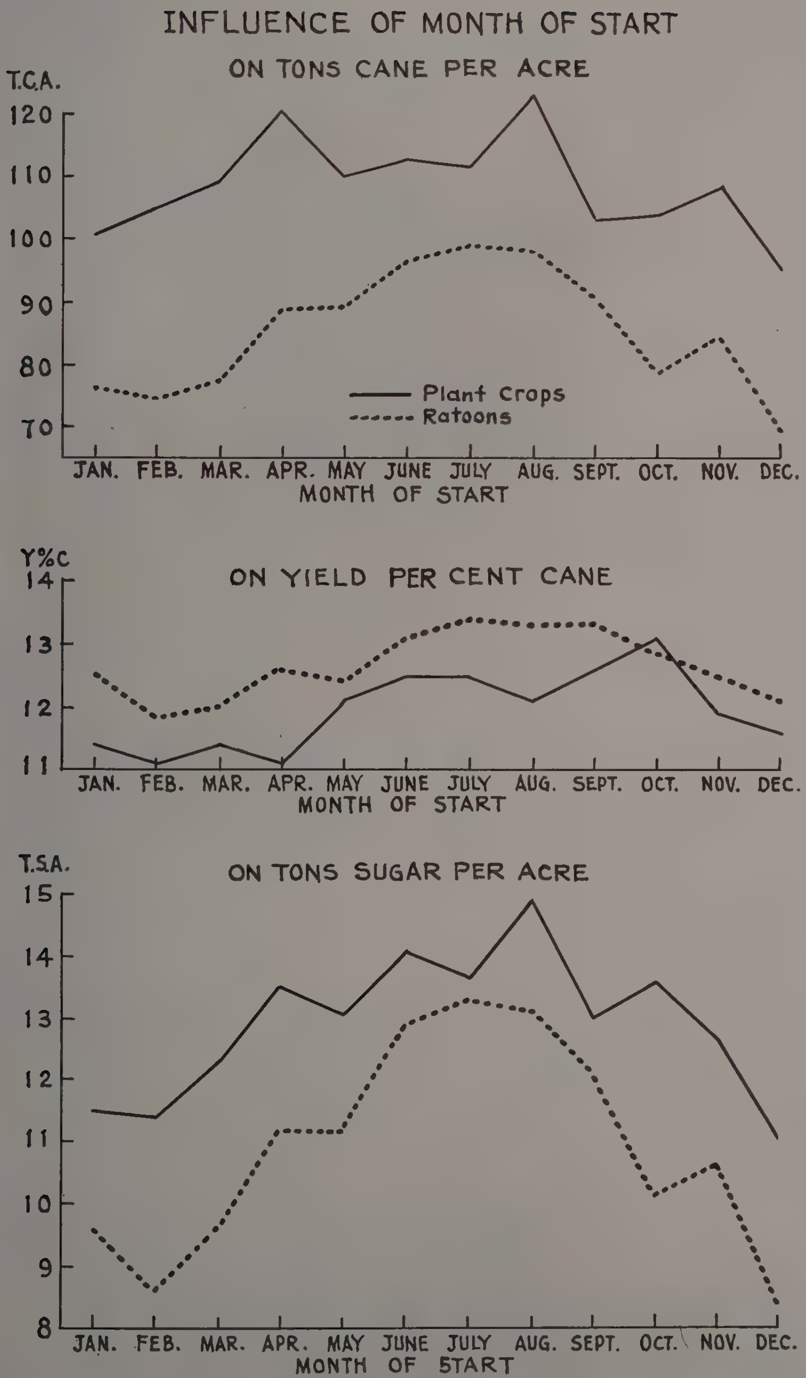

INFLUENCE OF MONTH OF START
ON TONS CANE PER ACRE
T.C.A.
120
110
100
90
80
70
Plant Crops
Ratoons
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
MONTH OF START
Y%C
14
13
12
11
ON YIELD PER CENT CANE
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
MONTH OF START
T.S.A.
15
14
13
12
11
10
9
8
ON TONS SUGAR PER ACRE
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
MONTH OF START

Fig. 11

the earlier- and later-started crops; this was also true of the yield per cent cane. Thus, in so far as recoverable sugar yields are concerned, we have pretty good evidence of the superiority of certain seasons in which to start H 109 cane crops in locations similar to Waipio where these canes were grown.

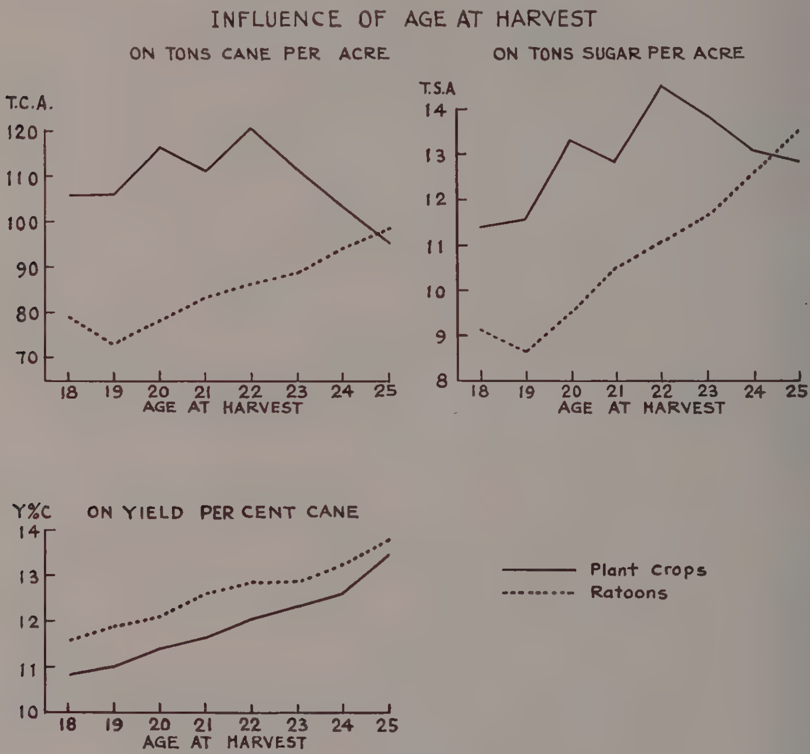


Fig. 12

The influence of age at harvest is shown nicely in Fig. 12. Cane yields from the plant crops fell off sharply after they reached the age of 22 months but this was not a feature of the ratoon yields which continued to increase up to 25 months. These same trends from age at harvest were characteristic of the sugar yields also. The improvements in Y%C reflect the beneficial effects of age upon juice quality, and we believe that this is one of the most significant facts which our investigation has furnished.

Fig. 13 shows that the plant crops had a lower percentage of glucose at harvest than the ratoon crops. Month-of-start effects on plant crops showed higher glucose from crops started early, but little difference was found in ratoons that could be the effect of time of start. The percentage of glucose decreased with age in both plant and ratoons, and at almost the same rate.

The relative rates at which these crops produced cane and sugar between 18 and 25 months is shown in Fig. 14. Tons-cane-per-acre-per-month fell off with increased age in the plant crops but was apparently maintained at a very uniform

rate in the ratoons. Sugar-per-acre-per-month dropped sharply after 22 months in plant cane but continued to increase from ratoons up to 25 months.

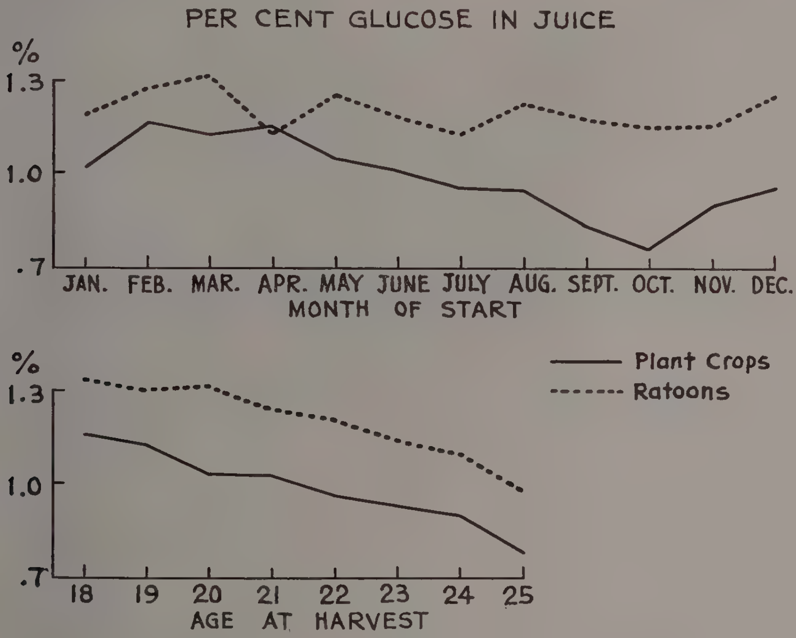


Fig. 13

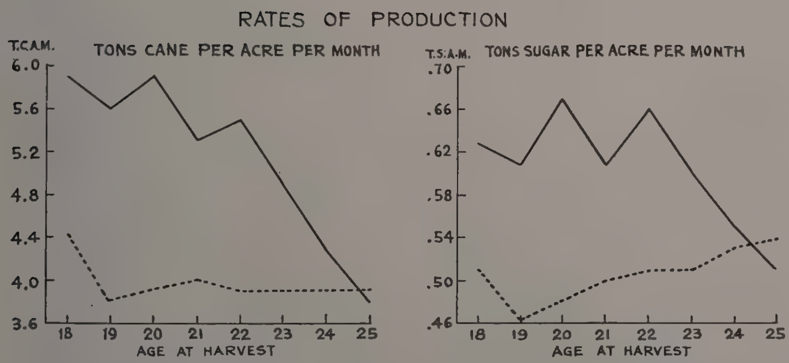


Fig. 14

An interesting relationship is shown in Fig. 15. The light lines show the effects of the month of start and the heavy lines the effects of the month of harvest, on the sugar yields. In these graphs, age at harvest is balanced since all ages from 18 to 25 months are included in each point shown. The relationship is not as clearly

seen from the plant crop data as from the ratoons, but it does appear that it will be well to avoid starting and harvesting H 109 crops during the slower growing months of the year.

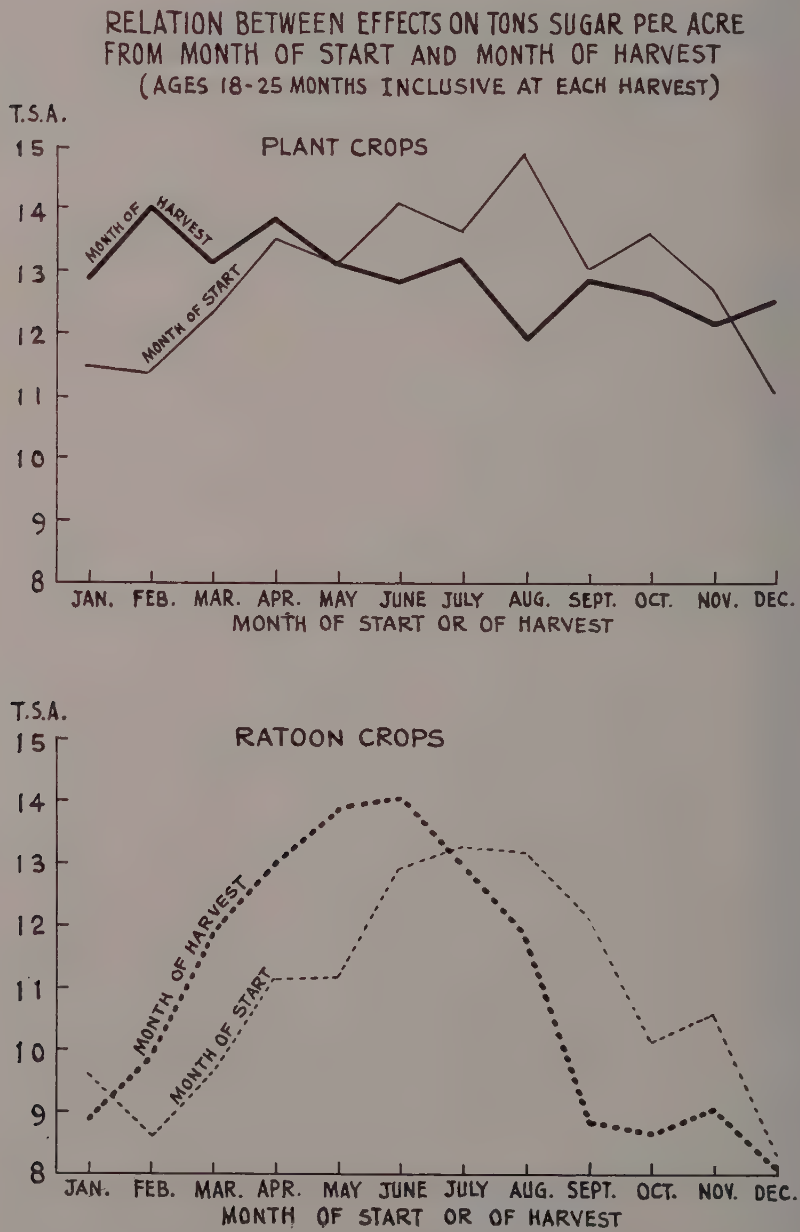


Fig. 15

Summary:

To summarize the data which were collected during this study we present a simple tabulation in which the relationships between the many different measurements are brought together in a brief and easily comprehensible form, as follows:

Measurements	On plant crops	On ratoons
Best age to harvest for sugar yields	22 mos.	25 mos.
Best age to harvest for cane quality	25 mos.	25 mos.
Best age to harvest for cane yields	22 mos.	25 mos.
Best months to start crops for sugar yields	Aug., June, July	July, Aug., June
Best months to start crops for cane quality	Oct., Sept., July	July, Sept., Aug.
Best months to start crops for cane yields	Aug., Apr., June	July, Aug., June
Poorest age to harvest for sugar yields	18 mos.	18 mos.
Poorest months to start crops for sugar yields	Dec., Feb., Jan.	Dec., Feb., Jan.
Miscellaneous statistics*		
Average tons cane/acre, and (tons cane/acre/month)	109 (5.1)	85 (4.0)
Average tons sugar/acre, and (tons sugar/acre/month)	12.9 (.60)	10.9 (.50)
Average yield per cent cane	12.0	12.7
Average % glucose in crusher juice	.99	1.21
Average % P_2O_5 in crusher juice	.026	.027
Average % K_2O in crusher juice	.057	.053
Average % N in crusher juice	.012	.013
All millable stalks at harvest: No. per foot of row	2.92	2.65
Average length	14.0 ft.	12.7 ft.
Wt. per ft. of stalk	.63 lb.	.59 lb.
Non-millable stalks at harvest: No. per ft. of row	.30	.40
Dead stalks at harvest: No. per ft. of row	.64	.96
Selected stalks measured: Length at 8 months	6.4 ft.	7.1 ft.
Length at 16 months	13.1 ft.	13.6 ft.
Length at 24 months	17.4 ft.	18.3 ft.
Monthly elongation of measured stalks	.67 ft./mo.	.68 ft./mo.
Average number of day-degrees	12.2	13.2

* Averages from all ages at harvest and all months of start.

Edible Soybean—A Food Crop for Hawaii

By C. G. LENNOX

The edible soybean assumes a position of prominence as a source of substitutes for animal proteins and oils in Hawaii's program of self-sustenance.

The high protein content of the green shelled beans, quickness in developing a crop, freedom from serious insect pests and diseases, and cheapness of planting, cultivating and harvesting in terms of man-days per ton of green beans, all contribute to the value of the soybean as an emergency food crop.

Success with the year-round production of soybeans in Hawaii hinges principally upon the correct choice of varieties for planting in the different seasons; secondly upon sufficient fertilization with nitrogen and phosphorus.

The production of diversified food crops for local consumption has taken on a new significance for Hawaii since this Territory has become the front line in a war zone. The fact that local production of crops in this category has fallen far below the local consumption is due to the prevalence of insect pests, a climate unfavorable to the crops, and the prevailing economic setup. Economic values need not be considered in a situation where it is a matter of eating or going hungry, but insect pests must be controlled if we are going to grow the crops which they attack, and the climate is, of course, quite beyond our control. If we are to grow diverse food crops, it becomes necessary to select crops which will afford us the necessary nutrients, make a reasonable growth under our climatic conditions and survive the attacks of the insect pests which we are unable to bring under complete control. Among the crops which fulfill these requirements, the soybean appears to rank very high and is one of the most reliable food crops for us to grow to meet this wartime emergency.

The Growth of Soybean Production in the United States

It is estimated by one authority that the soybean has been highly prized in China for more than 25,000 years. Although introduced into the United States in 1804, it passed unnoticed for the first hundred years with only small plantings in some of the southern states. By 1919 a fairly uniform development was occurring in states east of the Mississippi with considerable prominence in the New England states and some interest in certain southern and mid-western states. The crop was beginning to show some importance in 1924 when approximately one-half million acres were harvested for beans with a production of five million bushels.

The dramatic story of the soybean increase in the United States starts with 1924. Table I shows a consistent doubling of production until 1934 after which it is more than tripled.

TABLE I

ANNUAL SOYBEAN ACREAGES, YIELDS, AND PRICES IN THE UNITED STATES
(Adapted from Kiesselbach and Lyness [7])

Year	Acres harvested for beans	Yield of beans per acre—bushels	Total production—bushels	Average price per bushel paid farmers
1924	448,000	11.0	4,947,000	$2.46
1929	708,000	13.3	9,398,000	1.88
1934	1,539,000	15.0	23,095,000	.99
1939	4,417,000	20.7	91,272,000	.81
1941	5,855,000	18.2	106,712,000	1.47

Note: The standard weight of one bushel soybeans is 60 pounds.

Kiesselbach (7) points out that the importance of soybeans in the United States can hardly be overstressed as a vital necessity of wartime production and states that the Secretary of Agriculture has requested a 54 per cent increase in the country's acreage to be harvested for beans in 1942. This will jump the acreage from 5,855,000 acres in 1941 to 9,000,000 acres in 1942. In spite of the fact that the supply is greatest in history, the Chicago cash price for soybeans was 84 per cent higher on January 30, 1942 than the pre-war average of 1935-1939.

It is interesting to examine the position of the United States in the world production of soybeans. Table II shows that in 1935 next to Manchuria the United States was the second largest producer. These figures, however, do not include production in China which according to estimates leads all others. Figures later than 1935 are not available due to war conditions, but judging from the estimated production for 1942 of 140 to 150 million bushels it is expected that the United States will become second only to China in world production of soybeans.

TABLE II

COMPARATIVE WORLD PRODUCTION OF SOYBEANS
(Adapted from Grove [4])

	Bushels 1930	Bushels 1935
U.S.A.	13,471,000	44,378,000
Manchuria (not including China)	196,944,000	141,793,000
Korea	22,989,000	22,401,000
Japan	14,381,000	10,717,000
Netherland Indies	4,692,000	7,448,000

Vegetable oil, industrial oil for paints and varnishes, plastics, and high-protein stock feeds have been the stimuli for increased production so far. Its direct uses for human food have been of minor importance. Burlison (2) lists the products derived from soybeans grown in the United States and actually placed on the market in the United States and Canada during the latter part of 1931:

Food Products

Soybean flour	Oleomargarine
Soybean meal flour	Lard substitutes
Refined edible soybean oil	Filled sweets
Soybean salad oil	Soybean sprouts
Chocolate bars (30% soybean flour)	Soybean cheese
Cocoa (up to 60% soybean flour)	Soya cream biscuits
Sausages (up to 50% soybean flour)	La Choy-Soy sauce
Bread (7½% soybean flour)	Zoybeans (cooked beans)
Rolls (10% soybean flour)	Bacon and Zoybeans
Macaroni (20% soybean flour)	Zoy Bouillon
Soybean muffins	Casein gluten flour
Soybean cookies	No-fat mayonnaise
Soybean doughnuts	Fatless spread
Vegetable shortening	Soyex-Malt-Cocoa drink
Infant foods	Soybean milk
Diabetic foods	Soybean ice cream

Feed Products

Cake or Meal	Dog chow
Commercial feed	Calf chow
Dairy feed	Rabbit chow
Hog chow	34% protein chow chow
Poultry chow	Chick startena

Industrial Products

Paint	Lauxtex plastic wall coat
Varnish	Lauxein waterproof soybean glue
Enamels	Lauxein emulsifier
Oilcloth	Soap
Linoleum	Core binders
Printers' ink	Rubber substitutes
Glycerine	Plastics
Celluloid	

Soybean Flour as a Human Food

The principal interest of this discussion is the soybean as a human food. Horvath (6) in discussing soybean flour points out that numerous brands were on the market in 1931, but only one of them can claim to have met with real success, because flour from whole ground beans has a peculiar beany taste and cannot be kept or transported on account of its rapid deterioration. It acquires a bitter taste and repugnant odor in a very short time.* The one exception is a flour, developed and patented by Professor Barszeller working in Vienna, in which the obnoxious constituents were eliminated by special milling and fractional distillation. It is

* Research in soybean flour during the past 10 years in the U.S. has developed methods of producing good quality flour by cleaning the beans, steaming, drying, hulling, and then milling. LeClerc (8) discusses process of flour making and uses.

completely free from bitter flavor and can be stored indefinitely. This patented soybean flour is called "Soyolk". Horvath reports on the work conducted by numerous nutrition and bakery experts in Holland, Hungary and Austria in which they have tested the value of "Soyolk" and report satisfactorily on its value. A typical report, from F. A. Richter, baking expert of the Nutrition Laboratory of Vienna, states: "We took special care not to deviate from the customary flavor, taste and outside appearance of the various kinds of bread used in different countries (England, Scotland, Wales, Ireland, France, U.S.A., etc.). In none of these tried methods of making bread by adding soya flour in the above proportions could any essential change in flavor, or texture, be discovered in the bread. On the contrary, it improved the flavor of a Viennese roll and gave it a tempting appearance. We can say the same of the dark loaf of Germany, of the American cream cracker biscuit and the English wholemeal loaf."

The high protein and fat content of soybean flour places it as a valuable meat substitute in emergency rations or low-costs diets. Horvath quotes Dr. Kupelwieser as stating that 1 kg. of "Soyolk" is equivalent in protein to 2.5 kg. lean boneless beef, or 67 eggs, or 13.7 liters of cow's milk. The following is the average composition of wheat and soybean flours and gives an indication of the relative contribution of nutrients by each.

	White Flour* Wheat	Flour* Soybean
Protein	10.8	37.3
Carbohydrate	75.6	9.5
Fat	.9	20.2
Crude Fibre	.3	2.5
Ash	.4	4.7

* Nutritional Charts—Research Department, H. J. Heinz Co.

The work referred to above by Horvath was taken from reports coming from Europe during 1928-1930. Work with the soybean flour in Germany apparently has continued until today it occupies a very important position in German war plans. The following statement appears in the July 1942 issue of the *Nutritional Observatory* (5): "Because of the relative lack of foodstuffs of animal origin in Germany, the Nazis are making the fullest possible use of soy-flour as a food weapon in the present conflict, particularly as a substitute for animal protein. Soy protein is more like animal protein than any other vegetable product. Low cost of the flour is an added advantage. At the end of the Polish campaign Nazi official circles stated that without soybeans it would not have been possible for the German Army to advance so quickly."

A further reference to the importance of soybean flour in the German war effort appears in *Time,* June 15, 1942, in its review of the motion picture *Food*. It states that: "Farmers grow what they are told to grow, and the soybean (twice the strength of meat at a quarter the price) is the armed forces' basic ration. It is mixed into almost every dish the soldiers eat and, *Food* suggests, may even be Hitler's vaunted secret weapon."

Classification of Soybeans

The many varieties of soybeans may be grouped into three special-purpose categories:

1. Forage types which produce a large volume of stems and leaves suitable for hay or green feeding and are comparable with alfalfa in available nutrients.

Two extremes of the soybean varieties planted June 2 on adjoining beds at Kailua and photographed on August 20, 1942. The variety at the left is late-maturing forage type (Java 29) which is just beginning to flower. The variety at the right is an early-maturing vegetable type (Hahto) which flowered on July 14. The beans are now optimum for using as green shelled beans. Note the Chinese rose beetle damage starting on the late-maturing variety while the early-maturing one has set a full crop with little damage.

2. The industrial types which are harvested as dry beans for their high oil and protein content. Most of the acreage planted for dry soybeans in the United States is in varieties of this type.

3. The green-vegetable or edible types which are palatable as human food. They differ from the industrial types in that the beans are larger, easier to cook and do not have a strong, raw bean flavor.

The interest in varieties suitable for green-vegetable beans is of recent origin in the United States. It was only ten years ago that United States agricultural explorers in the Orient made a project of seeking out the varieties that were used solely as green-vegetable or dry edible beans, and were able to collect more than 100 varieties for this country.

The green-vegetable or edible types are the soybean varieties which have promise for Hawaii as a valuable food crop. The discussion in this paper will deal principally with this type.

Nutritional Value of Green Edible Soybeans

The edible soybeans are ready for consumption as a green vegetable in 60 to 70 days after planting and will be a source of highly nutritious food soon after any food shortage may be predicted. They can be harvested with existing machinery and readily transported to the centers of population.

Analyses of the Seaweed variety of green edible soybean grown in Hawaii appears in Table III. These analyses agree closely with similar ones made on the mainland.

TABLE III

NUTRIENT COMPONENTS OF GREEN VEGETABLE SOYBEANS, LIMA BEANS, AND STRING BEANS (KIDNEY) IN RAW GREEN STAGE

	Protein %	Fat %	Carbo-hydrate %	Calories per 100 gm.	Ca %	P %	Fe %
Soybeans (green shelled raw)*...	12.5	5.1	10.0	130	.063	.239	.00283
Lima Beans (green shelled raw)†	7.5	.8	22.0	125	.028	.133	.0022
String Beans (green raw)†......	2.4	.2	6.3	37	.046	.052	.00093

* Adapted from Miller (10). † Nutritional Charts, Research Department, H. J. Heinz Co.

A situation which would call for supporting the Hawaiian population on locally grown food would find a real deficiency in foods sufficiently high in fat and protein for balanced diets. Crops presently under cultivation are low in these nutrients, therefore the problem becomes one of searching out suitable crops to amend this deficiency. The legumes are the principal sources of proteins in the plant kingdom. Table III gives the comparative composition of three legumes which may be grown successfully in Hawaii, while Table IV gives the estimated yields per-acre-per-month of protein and fat. Soybeans lead all others in protein and fat production per-acre-month by a wide margin.

TABLE IV

ESTIMATED YIELDS OF CALORIES, PROTEIN, AND FAT PER-ACRE-PER-MONTH

Legume	Est. yield* lbs./ac.	Months to completion of harvest	Est. yield ac./mo. lbs.	Calories ac./mo.	Lbs. protein ac./mo.	Lbs. fat ac./mo.
Kidney Beans (green string)	5,000	2.3	2174	364,000	52	4
Lima Beans (green shelled)	4,000	4.0	1000	566,000	75	8
Soybeans (green shelled)	3,000	2.3	1304	768,000	163	67

* Based on field and experimental experience at Kailua and Waipio substations in 1941 and 1942. Yields on soybeans based on plantings made during months of April to July.

The proteins of legumes in general are of poor biological quality as compared with animal proteins and cannot be taken at their analyzed value in balancing rations. However, the proteins of the soybean are an exception and are ranked on a par with animal and fish proteins in biological value. Sherman (11) points out that the soybean is markedly improved by cooking and biological tests have shown that the protein of soybeans is definitely superior to that of cowpeas when subjected to the heat treatment ordinarily used in preparing them for human food. The protein of several cooked edible varieties very nearly equal casein, the chief protein of milk.

Soybean oil possesses qualities which make it desirable for food and much of the extracted oil is used in the shortening and margarine industries.

The carbohydrate value of soybeans is low, but since this nutrient is available in excess from sugar, sweet potatoes, bananas, and concentrates which are easily stored it carries small importance.

The mineral composition of the green edible soybean is well above that of other beans. Miller (10) points out that the calcium content of the cooked green beans of the Seaweed variety carried .098 per cent calcium, which compares favorably with that of milk. The phosphorous content on the other hand is higher than milk, while the iron content exceeds that of most common vegetables. The green edible soybean is a good source of vitamins A and B_1.

Cartter (3) shows that the percentage and quality of oil are influenced by the existing environment during the entire growth of the plant. Likewise, the percentage of carbohydrate, protein and mineral constituents may be influenced by soil and environment.

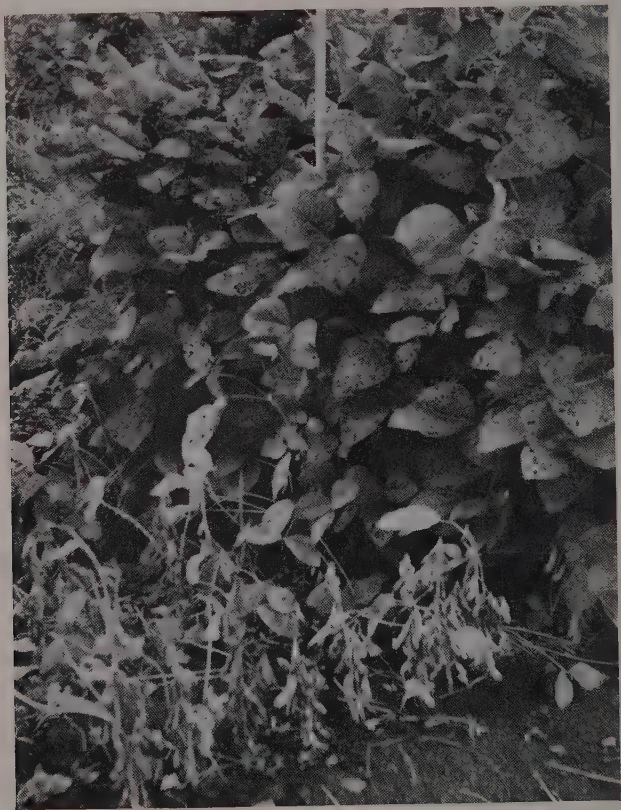
The Soybean in Hawaii

The edible soybean is not new in Hawaii. The annual report for 1908 of the Hawaii Agricultural Experiment Station states in reference to soybeans: "A green seeded type has been grown in the Kona District of Hawaii for some years." The reports of 1932 through 1935 from the same Experiment Station tell of the importations of many varieties for trial. Preliminary trials were also made on the green-vegetable types.

Cultural Requirements:

Although growing conditions in Hawaii are suitable for a year-round production of most vegetable crops we find the soybean an exception. It is a plant whose time of flowering responds to the length of day rather than temperature.

The soybean is one of a large group ~~of plants which~~ flowers under the stimulus of a long period of darkness. Although the day length of the shortest day in Hawaii is only two and one-half hours shorter than the longest day this is quite sufficient to have a profound effect on the soybean. During the summer season the plants come into flower in exactly the same length of time as recorded on the mainland, but as the days shorten the flowering commences sooner. Nearly all the flowers bloom at the same time on the soybean plant and if the flowering is initiated before a full-size plant has developed, the number of flowers is proportionately



Extremes in maturity of green-vegetable type soybeans. Both varieties planted May 20, and photographed August 20, 1942. The variety in the foreground is Hokkaido, an early-maturing type which reached the vegetable stage on August 1. The variety in the background is Giant Speckled, a late-maturing type. It will not reach the green-vegetable stage for fifteen days, and did not produce a heavier crop of green shelled beans than the Hokkaido.

When planted after September the Giant Speckled will develop a small plant about the size of the Hokkaido pictured above.

reduced. The reduction in number of pods per plant results in a reduced yield per acre. It is this stimulus of the short day resulting in small crops that has retarded the interest in soybeans as a vegetable crop for Hawaii.

Varietal Characteristics:

The green-vegetable type soybeans are classified according to maturity under summer length of day. The early-maturing groups are small plants with the pods usually clustered close to the ground. They reach the green-vegetable stage in 60 to 70 days. The medium-maturing groups reach the green-vegetable stage in 70 to 90 days. They are bigger plants and the pods are usually dispersed over the length of the main stem. The late-maturing groups reach the green edible stage in 100 to 120 days. They are large plants from 3 to 4 feet tall with the pods thinly distributed over the upper three-fourths of the plant. The many varieties under trial show a full range of intermediate stages within these three general classifications.

The different varieties planted throughout the year show a changing time of maturity which is an integration of the genetic maturity of the variety and the current length of day. In other words, a late-maturing variety continues to be a late-maturing variety under the shortest day length but matures earlier, while the early-maturing ones are proportionately earlier. The problem of selecting a variety for Hawaiian conditions therefore becomes one of choosing a genetic maturity to compensate for the day length during the season it is to be grown. For early summer planting the early-maturing type should be selected, for midsummer a medium-maturing type, while during late summer and winter months only late-maturing varieties should be planted. By this judicious selection of varieties reasonably good yields may be expected the year-round.

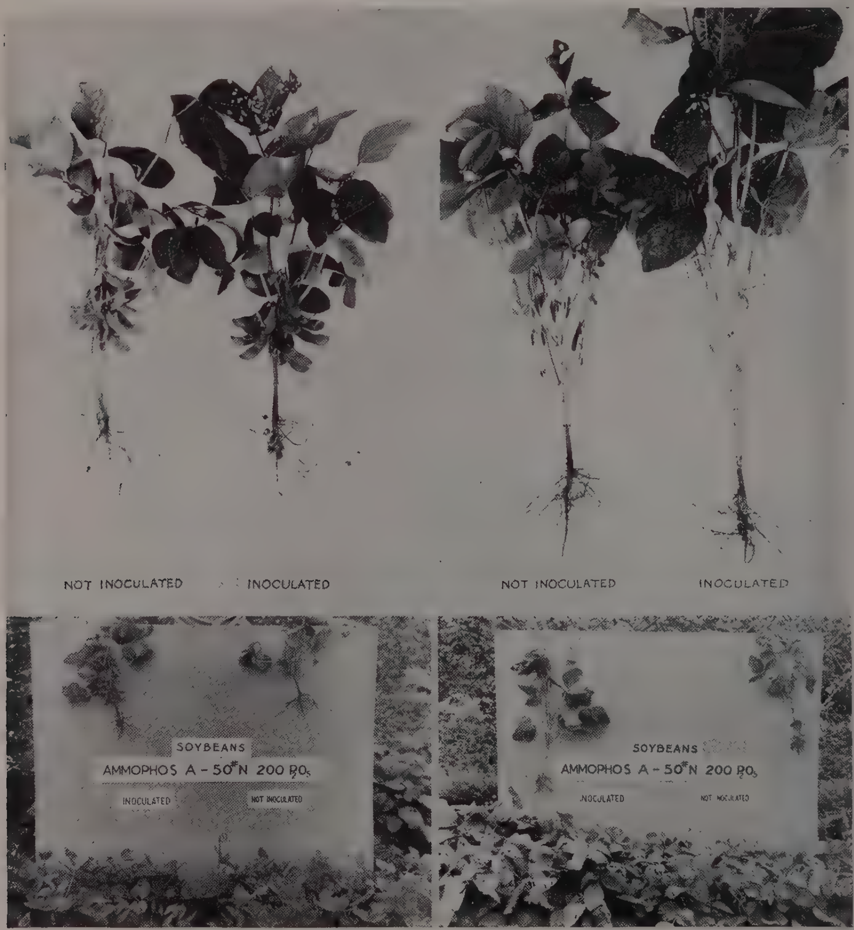
Soil:

The experience so far indicates that an acid (pH 6 or below) soil is not favorable for the best soybean growth. Such a condition is not conducive to the development of nitrogen-fixing bacteria and the plant is not vigorous. Heavy alluvial soils in valley bottoms have given the finest growth and seem well suited to the soybean plant. The red residual soils, typical of leeward sugar cane conditions, have produced equally good crops providing they are deeply plowed, well fertilized and irrigated. The soybean plant although having a small root system is deeply rooted. It sends its roots to a depth of from 3 to 5 feet and responds to well-prepared and deeply plowed seed beds. It is highly reactive to poor spots in the field, such as outcroppings of subsoil, areas underlain by gravel or sand wash, and in fields of spotty soil depth or fertility the locations of the poor areas are brought into sharp relief by a population of soybean plants.

Fertilization:

Nitrogen: The soybean is a legume and if the seed is inoculated with the proper nitrogen-fixing bacteria immediately before planting it will obtain some of its nitrogen requirement from the air. However, it requires available nitrogen in the soil to carry on maximum growth during the first 30 days because the nitrogen released to the plant by the nitrogen-fixing bacteria is not appreciable until nodulation is well advanced. On soils low in nitrogen, especially following a crop of sugar cane, the experience has been that between 50 and 75 pounds of nitrogen per acre must be added. Judging from observation tests at both Kailua and Waipio

the nitrogen should be from an ammoniacal source such as ammonium sulphate or Ammophos. Nitrate nitrogen is reported to inhibit the development of nitrogen-fixing bacteria.



Inoculation of soybean seed with the proper nitrogen-fixing bacteria has a more pronounced effect on the late-maturing varieties than on the early-maturing ones. The variety at the left is an early-maturing type, although nodulation has been heavy there is little improvement in yields. The variety at the right is a late-maturing type and is benefiting from the nitrogen supplied by the nitrogen-fixing bacteria. Both varieties planted March 9, 1942 at Waipio.

No appreciable benefits from inoculation have been noted on the early-maturing varieties in the many trials conducted at both Kailua and Waipio. In these varieties the plant reached nearly full maturity in 30 days and was beginning to flower. However, on the late-maturing varieties a very marked benefit from inoculation has been noted. In these cases the plant did not reach the flowering stage until 60 or 90 days from planting and developed 2 or 3 times the vegetative matter

that the early-maturing varieties did. It is estimated that these varieties obtained two thirds of their nitrogen requirement from the air and approximately one third from the soil. Inoculation of seed with nitrogen-fixing bacteria was worth while in either case because of the increase in nitrogen in the roots after the crop had been harvested and thereby increasing residual nitrogen for succeeding crops.

The soybean is different from most legumes in that only one tenth of the nitrogen in the plant is in the root system. Thus when most of the plant is removed from the field, as would be done with the edible types in Hawaii, there remains little of the plant material to supply residual nitrogen for the following crop. Besides the small increase in residual nitrogen, Sears (13) points out that land on which a crop of soybeans has just been grown usually "works well and is easily put in shape for seeding of other crops." This is the characteristic residual effect of most legumes. The improved physical condition of the soils also favors the development of micro-organisms which require plenty of oxygen. Sears presents data following a 36-year rotation of soybeans, corn, corn, corn rotation, which show the residual nitrogen, micro-organisms, and yields of corn decrease on successive years planted to corn following a crop of soybeans.

TABLE V

SOIL PROPERTIES IN SOIL AT URBANA, ILLINOIS, PLANTED FOR 36 YEARS IN A SOYBEAN, CORN, CORN, CORN ROTATION

(Adapted from Sears [13])

Year after soybeans	Pounds NO_3* per acre soil	Millions of micro-* organisms per gram air dried soil	Yield corn bushel per acre (36-year average)
First year	27.7	14.5	50.7
Second year	16.4	11.2	46.3
Third year	13.3	9.5	42.3

* Nitrate analyses and micro-organism counts made in 1928. Yield figures are averages for 36 years.

It might be suggested that sugar cane would benefit as corn does after a crop of soybeans since both have somewhat the same feeding requirements.

Phosphate: Phosphate fertilization is second only to nitrogen in importance for securing a heavy crop under Hawaiian conditions. Noticeable benefits have been observed on nearly all soils, some of which are considered high in phosphate by sugar cane standards. The phosphate should be placed in the furrow under the seed.

Potash: No benefits have been observed from potash fertilization on the Experiment Station areas where soybeans have been tested. One of the fields at the Kailua substation which is very low in potash by sugar cane standards (less than 70 pounds per acre-foot) has shown no benefits from potash in repeated N-P-K-observation tests.

Irrigation:

Although the soybean plant is deep rooted and reported as drought resistant on the mainland the experience in the Experiment Station plantings at both Kailua and Waipio is that it needs a liberal moisture supply until the pods are well formed. Deficiency of moisture during the early periods of growth results in a small plant at flowering time and a correspondingly reduced yield.

Planting:

The edible types favored for summer planting are early-maturing small plants and can be planted in rows 24 to 30 inches apart with the seeds spaced 1½ to 3 inches in the row. The same distance applies to the winter planting where the late-maturing varieties are used, since under these conditions the plants attain a size comparable with the early-maturing types in summer time.

Forage types develop large rank plants and should be planted in rows 36 to 48 inches apart. They should only be planted between the months of March and August as earlier or later plantings are sensitive to the day length and mature before developing a worth-while tonnage of green material.

In both cases the seed should be covered to a depth of ½ to 1½ inches, with shallow covering for heavy soils and deeper covering for light open soils. Uniform depth of covering is important since delayed germination means delayed maturity and it is undesirable at harvest time to have scattered areas in the field at different stages of maturity than the general average.

Harvesting:

Edible Types as Green Beans: Most of the pods on the plant are at the same stage of maturity. They are ready to harvest as green beans when the seed is fully swollen and usually remain at this optimum stage for a period of one week to ten days. Some varieties show the approach of this optimum stage by the lower leaves yellowing and dropping, while others maintain a normal healthy leaf system throughout the entire stage and the decision as to maturity must be made by examining the beans in the pods.

Harvesting is done by cutting the main stem at the ground level and sending the entire bush with its load of pods to the market. If the culture has been a flat one or the plants have been slightly hilled up they can be cut mechanically with a grain or hay cutter. Harvesting by hand with a stout grass knife or cane knife is a cheap operation and results in a cleaner product for the market. Stripping the pods from the plant is an operation left to the purchaser.

Edible Types as Dry Beans: After the plant has passed the stage for harvesting as green beans the leaves begin to yellow and fall off while the pods turn yellow and then a dark brown. As the plant reaches its last stage of maturity it is bare of leaves. The pods of most of the edible types will tend to shatter in the field when they become fully dried with a resulting loss of beans. To avoid this they should be cut when the beans reach a "hard dough" stage and piled in windrows and allowed to cure for five or six days. If the cutting is done in the morning when the plants are damp there is less loss from shattering of mature pods. An ordinary grain thresher can be used for threshing out the beans if the cylinder speed is reduced to 2,300 to 2,500 feet per minute. Sjogren (12) recommends that the number of rows of teeth in the lower concave be reduced to one or two and blanks substituted. This will give complete threshing and reduces the percentage of broken beans.

Forage Types for Green Feed, Hay or Silage: The forage types reach their optimum protein content when the pods are just beginning to fill. However, harvesting can be done at any time after the pods have set and until the leaves begin

As the beans on the soybean plant reach full maturity the pods turn brown and the leaves drop off. This planting of the early-maturing edible variety ''Seaweed'' will be ready for threshing in two weeks.

This forage variety (Java 29) was planted on June 2 at Kailua and photographed on August 20, 1942. It will be prime for cutting for green feeding or silage any time from August 20 to September 15. Forage types do not produce sufficent green material to warrant planting if planted later than July or earlier than March.

to yellow. In the summer time this is a period of 30 to 50 days. The forage types should be grown on flat culture or with irrigation furrows between the rows so that they can be harvested and raked mechanically.

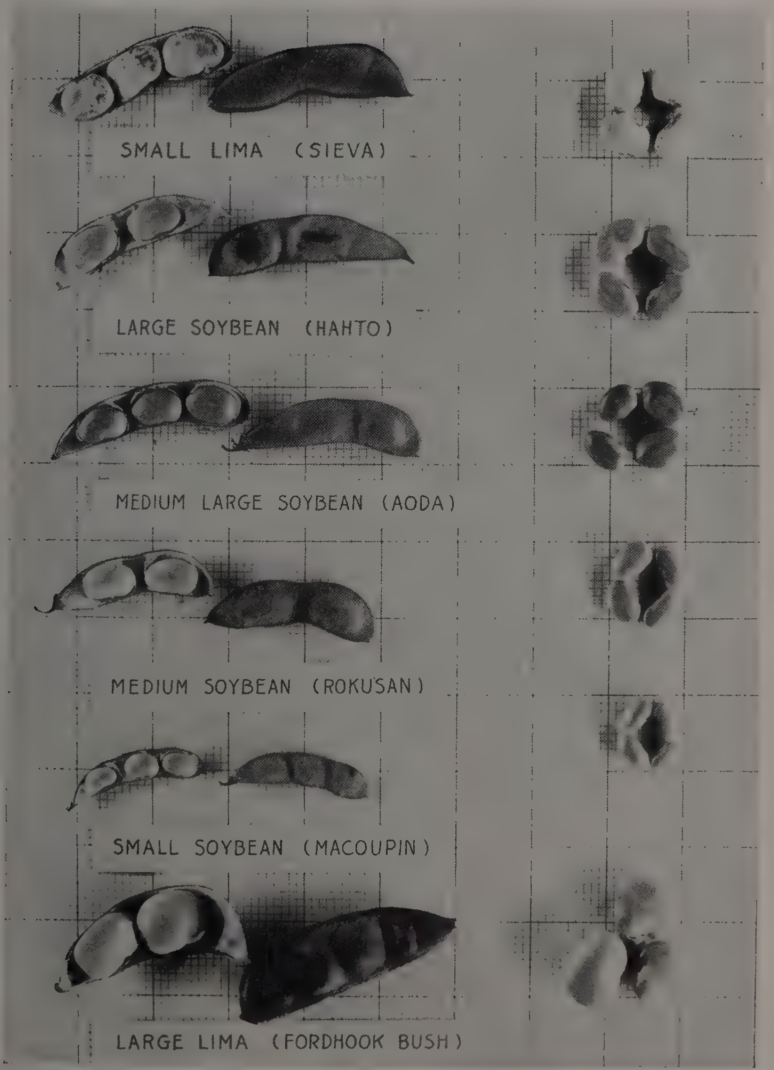
Insect Pests:

The Chinese rose beetle *(Adoretus sinicus)* is the most serious pest of soybeans. Its damage is most pronounced on the late-maturing varieties and can increase to such an extent as to materially reduce yields. The early-maturing varieties, however, have set their crop before damage becomes extensive and yields are not affected. When late-maturing varieties are matured early under the influence of the short day the rose beetle damage is not serious.

A heavy-bearing soybean variety from South Africa. It is a late-maturing type and consequently suffers from Chinese rose beetle damage to the leaves. This is not an edible type, but belongs to the group whose beans are used in industry.

Doves have constituted the only other pest that has done damage of serious proportions in Hawaii. Their damage is done during the two or three days when the swollen cotyledons are exposed above the ground before the first leaves unfurl. In small plantings this damage may be considerable, as the doves will nip off every cotyledon in sight.

The green leafhopper *(Empoasca solana)*, the bean capsid *(Pycnoderes quadrimaculatus)*, and the white fly *(Alcurodes vaporariorum)* which at times cause so much damage to both kidney and lima beans have never been noted as serious on the soybean. The bean-pod borer *(Maruca testulalis)* which damages both kidney and lima beans has never been noted on the soybean. The dry beans are always free of bean weevil damage (Bruchus species) which has been observed to infest



Some varieties of soybeans have a bean as large as the baby lima bean. The large bean varieties usually rank highest in palatability tests and also offer less difficulty in shelling out after cooking.

kidney beans before and after threshing. This observation coincides with the recommendations of Boswell (1) that dry edible field bean crops should not be attempted in regions threatened with midsummer showers because of unavoidable infestation by bean weevils. A moth *(Ephestia cautella)* will attack the dry beans when stored in the open.

The soybean is not beset with the insect problems confronting both kidney and lima bean production and it dries to a moisture percentage which will permit storage.

Diseases:

The experience gained so far shows the soybean to be free of serious diseases in Hawaii.

Bacterial blight caused by *Bacterium glycineum* has been noted on nearly all varieties. It is manifested by angular spots which are at first translucent, then yellow, and finally a dark brown which gives the general appearance of rust on the leaves. The spread of the disease is favored by frequent showers or overhead irrigation. In no cases has it assumed serious proportions on the early-maturing edible types. However, on some forage varieties which are late maturing the disease has gained some headway and it is important that the degree of susceptibility be determined for a variety before it is planted to a field scale.

Variety Selection:

The work of the Experiment Station on the soybean has been primarily one of testing hundreds of varieties and selections submitted by mainland correspondents.* As the project has progressed a clearer conception of standards required for edible soybeans in Hawaii has been developed. With the planting program continuing throughout the year it has been possible to classify varieties as to their suitability for spring, summer, late-summer, fall or winter plantings.

Considerable emphasis is placed on early maturity, since it is the best insurance against rose beetle damage and disease, and also is the quality required of a food crop for an emergency. The bean size also receives emphasis, with varieties of large bean size being preferred to ones of small bean size.

Taste tests are conducted on cooked beans of all promising varieties. In general it has been shown that the varieties with large beans are rated excellent in flavor and texture, while those with small beans are only fair to poor.

The elimination of poor varieties is still in progress, but at the present writing the following would be named as among the best for planting at the different seasons of the year:

* Acknowledgment: Dr. W. J. Morse, Senior Agronomist, Division of Forage Crops and Diseases, U.S.D.A., has been most generous in supplying the project with many varieties of edible soybeans.

Months to Plant	*Variety*
March and April	Hokkaido Emperor Imperial
May and June	Hahto Sac Seaweed
July and August	Hokkaido Emperor Imperial Hahto
September through February	Seminole Giant Speckled

Harvesting Results from Preliminary Yield Trials:

In preliminary yield trials the following technique is used in securing the yields of green shelled beans per acre:

When a variety reaches the optimum green vegetable stage a ten-foot section is selected from the center line of a three-line plot where the stand is uniform. All plants are cut at ground level and weighed. A random subsample of one fourth of the plant population is taken from which all the pods are stripped. The percentage of total weight which is due to beans and pods is calculated. A second subsample of 20 pods chosen at random is then taken. The beans are shelled out and the percentage of bean weight to total pod weight is calculated.

The following data give examples of the yields obtained from varieties planted in a preliminary test at Waipio on May 20, 1942. It will be noted that the yields from the late-maturing varieties are not commensurate with the length of time required to develop them.

Variety	Days to harvest	Lbs. gr. plants/ac.	% Pods	Lbs. gr. pods/ac.	% Beans	Lbs. gr. shelled beans/ac.
Hahto 22	67	15,800	53	8400	53	4,450
Hahto 2b	74	12,100	62	7500	56	4,200
Sac	67	12,200	56	6820	56	3,960
Hokkaido	67	14,800	52	7700	52	4,000
Imperial	67	14,200	49	6950	53	3,700
Emperor	67	16,800	43	7230	52	3,750
Seaweed	74	15,200	47	7180	51	3,650
Macoupin	83	14,800	48	7110	54	3,850
Seminole	101	22,700	39	8850	45	3,970

Supplementary data are also taken on each variety at harvest which are of value in interpreting their relative goodness.

Variety	Plant size	Bean size	No. plants per 10′ section	No. pods per plant	No. beans per pod	Palatability of cooked beans
Hahto 22	Medium	Medium-Large	30	..	...	Excellent
Hahto 2b	Medium	Large	37	38	2.2	Excellent
Sac	Medium-Small	Large	26	34	2.1	Excellent
Hokkaido	Medium	Large	28	30	2.0	Excellent
Imperial	Medium-Large	Large	28	27	1.7	Excellent
Emperor	Medium-Large	Large	28	28	2.2	Good
Seaweed	Medium	Medium-Large	30	31	2.1	Good
Macoupin	Large	Small	35	37	2.4	Poor
Seminole	Very Large	Medium-Large	30	42	2.2	Good

A replicated test planted in the same field at Waipio on July 13, 1942 and laid out in a checkerboard arrangement with plot sizes the same as used in the preliminary test gave the following yields at 65 days after planting:

Variety	No. plots	Lbs. green shelled beans per acre	Gains lbs./ac.	Odds (by Student)
Sac	6	4342	725	12:1
Bansei (check)		3617		
Emperor	5	3790	75	....
Bansei (check)		3715		

It is interesting to note that per-acre-yield of green shelled beans is essentially the same in the July 13 planting as in the May 20.

Culinary Suggestions:

Directions for cooking and shelling green soybeans:

The green pods of the soybean are difficult to open and the beans cannot be shelled out like lima beans or peas. This difficulty is avoided by first cooking the beans in their pods and then shelling.

After washing the pods they should be covered with boiling water and allowed to boil slowly for one to one and a half hours. Add about two teaspoons of salt to a quart of water.

The shelling operation is easy after the beans are cooked. Drain and allow pods to cool. To shell out the beans pick up the pod and hold with both hands over the container which is to receive the shelled beans. Break the pods across the middle with one motion and squeeze out the beans. The green shelled beans can be served in any of the many ways used to serve green lima beans or peas.

Recipes for Dry Soybeans (14):

In cooking dry soybeans, they should be soaked in plenty of water for 3 or 4 hours, the water replaced by fresh water and cooked until soft. It generally takes longer to cook soybeans than navy beans. It is preferable to cook them in a pressure cooker for 30 minutes at a pressure of 15 pounds. The time and pressure vary with the variety of bean.

Soybean Milk: Soak one pound of dry beans in water for 3 or 4 hours and discard the water. Wash the beans with water several times, grind the moist beans as fine as possible, using water to assist. Add water to make the mixture 1 gallon,

and strain. The strained liquid is heated to about the boiling point, preferably in a double boiler, for 15 to 30 minutes. Sugar and salt are added to taste. Keep in cool place.

Soybean Cheese: Proceed as in making milk to the point of heating the strained liquid. The strained liquid is heated to about 190° F., but not to the boiling point. At this temperature dilute acetic acid or vinegar is added just to complete coagulation. If a comparatively low temperature is used, more acid is needed and the cheese is finer; if the liquid is nearly boiling, the cheese formed is in larger and harder masses. This is strained out and washed free from acid. Salt to taste. This cheese is rather mild in taste but is used in making croquettes, salads, sandwich spreads and other products.

Roasted Soybeans: (Method I) Soak dry soybeans overnight, or until completely swollen. Dry the beans between towels and fry in deep fat, a few beans at a time, for 5 to 8 minutes depending upon the size of the beans (temp. 350° F.). When they are slightly brown and crisp, drain, salt and use as salted peanuts would be used.

(Method II) Soak washed beans overnight. Boil them for one hour in salted water, spread in a shallow pan and roast in a moderate oven (350° F.) until browned. Sprinkle them with salt while still warm.

Soybean Nut Butter: Grind about 2½ cups of roasted soybeans and mix with about 2 tablespoons of purified soy oil or salad oil.

Baked Beans:
4 cups cooked soybeans
2 cups tomato pulp
½ medium sized onion—minced
2 slices green pepper—cut fine
3 large stalks celery—cut fine
½ tsp. salt.
1 tbsp. molasses
Bacon

Cook vegetables, add beans, salt and molasses. Cover with thin slices of bacon Bake slowly.

Soy Loaf:
2 cups soybeans cooked and mashed
½ cup bread crumbs
2 eggs
½ cup milk
2 tbsp. grated onion
4 tbsp. butter or shortening
½ cup water
1 tbsp. celery salt

Mix all ingredients. Put into a buttered pan and bake for 20 to 30 minutes. Serve with tomato sauce.

Soy Loaf No. 2:
1 cup cooked rice
1 cup cooked soybeans
2 hard boiled eggs—chopped
1 cup milk
1 tbsp. oil
1 scant cup bread crumbs
½ tsp. poultry seasoning
1 tbsp. minced onion
Salt to taste.

Mix and bake in a greased pan.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 15, 1942 TO JUNE 15, 1942

Date	Per pound	Per ton	Remarks
March 15,-June 15, 1942..............	3.74¢	$74.80	Philippines

TABLE OF CONTENTS